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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : C12Q 1/68		A2	(11) International Publication Number: WO 00/58516																		
			(43) International Publication Date: 5 October 2000 (05.10.00)																		
(21) International Application Number: PCT/US00/08069		(74) Agents: HOGLE, Doreen, M. et al.; Hamilton, Brook, Smith & Reynolds, P.C., Two Militia Drive, Lexington, MA 02421 (US).																			
(22) International Filing Date: 27 March 2000 (27.03.00)		(81) Designated States: CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).																			
(30) Priority Data: 60/126,473 26 March 1999 (26.03.99) US 60/140,359 23 June 1999 (23.06.99) US		(71) Applicants: WHITEHEAD INSTITUTE FOR BIOMEDICAL RESEARCH [US/US]; Nine Cambridge Center, Cambridge, MA 02142 (US). AFFYMETRIX, INC. [US/US]; 3380 Central Expressway, Santa Clara, CA 95051 (US).																			
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(54) Title: UNIVERSAL ARRAYS																					
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(57) Abstract																					
<p>An array of oligonucleotides on a solid substrate is disclosed, which can be used for multiple purposes. Methods and reagents are provided for performing genotyping to determine the identity or ration of allelic forms of a gene in a sample. A single base extension primer is coupled to a sequence identity code. During the primer extension reaction a distinctive label is incorporated which identifies the allelic form present in the sample. This permits multiple simultaneous analyses to be performed easily and efficiently.</p>																					

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UNIVERSAL ARRAYS

BACKGROUND OF THE INVENTION

Obtaining genotype information on thousands of polymorphic markers in a highly parallel fashion is becoming an increasingly important task in mapping disease loci, in identifying quantitative trait loci, in diagnosing tumor loss of heterozygosity, 10 and in performing linkage studies. A currently available method for simultaneously obtaining large numbers of polymorphic marker genotypes involves hybridization to allele specific probes on high density oligonucleotide arrays. In order to practice the method, redundant sets of hybridization probes, typically twenty or more, are used to score each marker. A high degree of redundancy is required, however, to reduce the 15 noise and achieve an acceptable level of accuracy. Even this level of redundancy is often insufficient to unambiguously score heterozygotes or to quantitatively determine allele frequency in a population. Thus, there is a need in the art for more reliable and better quantitative methods to identify genotypes at polymorphic markers.

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SUMMARY OF THE INVENTION

An array of oligonucleotide tags attached to a solid substrate is disclosed, along with locus-specific tagged oligonucleotides. The array and the locus-specific tagged oligonucleotides are particularly useful in genotyping using single base extension reactions. When used together, the array and the locus-specific tagged oligonucleotides serve as a "universal chip" system for use in genotyping, wherein by using different sets of locus-specific tagged oligonucleotides the system can be tailored to any desired genotyping application. For example, it is an object of the present invention to provide a method to aid in determining a ratio of alleles at a polymorphic locus. It is another object of the invention to provide a set of primers for use in determining a ratio of nucleotides present at a polymorphic locus.

Thus, in one embodiment the invention relates to an array comprising one or more oligonucleotide tags fixed to a solid substrate, wherein each oligonucleotide tag comprises a unique known arbitrary nucleotide sequence of sufficient length to hybridize to a locus-specific tagged oligonucleotide, wherein the locus-specific tagged oligonucleotide has at its first end nucleotide sequence which hybridizes to, e.g., is complementary to, the arbitrary sequence of the oligonucleotide tag, and wherein the locus-specific tagged oligonucleotide has at a second end nucleotide sequence complementary to target polynucleotide sequence in a sample.

In one embodiment, the invention relates to a kit comprising an array comprising one or more oligonucleotide tags fixed to a solid substrate, wherein each oligonucleotide tag comprises a unique known arbitrary nucleotide sequence of sufficient length to hybridize to a locus-specific tagged oligonucleotide, and one or more locus-specific tagged oligonucleotides, wherein each locus-specific tagged oligonucleotide has at its first (5') end nucleotide sequence which hybridizes to, e.g., is complementary to, the arbitrary sequence of a corresponding oligonucleotide tag on the array, and has at it's second (3') end nucleotide sequence complementary to target polynucleotide sequence in a sample.

The invention further relates to a method of genotyping a nucleic acid sample at one or more loci, comprising the steps of obtaining a nucleic acid sample to be tested; combining the nucleic acid sample with one or more locus-specific tagged oligonucleotides under conditions suitable for hybridization of the nucleic acid sample

5 to one or more locus-specific tagged oligonucleotides, wherein each locus-specific tagged oligonucleotide comprises a nucleotide sequence capable of hybridizing to a complementary sequence in an oligonucleotide tag and a nucleotide sequence complementary to the nucleotide sequence 5' of a nucleotide to be queried in the sample, thereby creating an amplification product-locus-specific tagged oligonucleotide

10 complex; subjecting the complex to a single base extension reaction, wherein the reaction results in the addition of a labeled ddNTP to the locus-specific tagged oligonucleotide, and wherein each type of ddNTP has a label that can be distinguished from the label of the other three types of ddNTPs; contacting the complex with an oligonucleotide array comprising one or more oligonucleotide tags fixed to a solid

15 substrate under suitable hybridization conditions, wherein each oligonucleotide tag comprises a unique arbitrary sequence complementary and of sufficient length to hybridize to a complementary sequence in a locus-specific tagged oligonucleotide, whereby the complex hybridizes to a specific oligonucleotide tag on the array; and assaying the array to determine the labeled ddNTPs present in the complex hybridized

20 to one or more oligonucleotide tags, thereby determining the genotype of the queried nucleotide in the sample. In one embodiment the nucleic acid sample to be tested is amplified.

In one embodiment a method is provided to aid in determining a ratio of alleles at a polymorphic locus in a sample. A pair of primers is used to amplify a region of a nucleic acid in a sample. In one embodiment, the region comprises a polymorphic locus, and an amplified nucleic acid product is formed which comprises the polymorphic locus. The amplified nucleic acid product is used as a template in a single base extension reaction with an extension primer, forming a labeled extension primer. The extension primer (also called a locus-specific tagged oligonucleotide herein)

comprises a 3' portion and a 5' portion. The 3' portion is complementary to the amplified nucleic acid product and terminates one nucleotide 5' to the polymorphic locus. The 5' portion is not complementary to the amplified nucleic acid product. A labeled dideoxynucleotide which is complementary to the polymorphic locus is coupled 5 to the 3' end of the extension primer. Each type of dideoxynucleotide present in the reaction bears a distinct label. The 5' portion of the extension primer is hybridized to one or more probes (also called oligonucleotide tags herein) which are immobilized to known locations on a solid support. The probes comprise a nucleotide sequence which is complementary to the 5' portion of the extension primer.

10 Also provided by the present invention is a set of primers for use in determining a ratio of nucleotides present at a polymorphic locus. The set includes a pair of amplification primers and an extension primer. The pair of primers prime synthesis of a region of double stranded nucleic acid which comprises a polymorphic locus. The extension primer comprises a 3' portion which is complementary to a portion of the 15 region of double stranded nucleic acid and a 5' portion which is not complementary to the region of double stranded nucleic acid. The extension primer terminates one nucleotide 5' to the polymorphic locus. Examples of primers according to the invention are shown in Table 1.

Another embodiment of the invention provides a method to aid in determining a 20 ratio of alleles at a polymorphic locus in a sample. Any nucleic acid molecule, including genomic DNA, which comprises one or more polymorphic locus is used as a template in a single base extension reaction with an extension primer, forming a labeled extension primer. The extension primer comprises a 3' portion and a 5' portion. The 3' portion is complementary to the nucleic acid molecule and terminates one nucleotide 5' 25 to the polymorphic locus. The 5' portion is not complementary to the nucleic acid molecule. A labeled dideoxynucleotide which is complementary to the polymorphic locus is coupled to the 3' end of the extension primer. Each type of dideoxynucleotide present in the reaction bears a distinct label. The 5' portion of the extension primer is

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hybridized to one or more probes which are immobilized to known locations on a solid support.

These and other embodiments of the invention which are described in more detail below provide the art with methods and tools for rapidly and easily determining 5 genotypes of individuals and allele frequencies in populations.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram of the universal array. The solid substrate (e.g., a glass slide) is depicted on the left, and different oligonucleotide tags ("A", "B", "C", etc.) are shown attached to the solid substrate. The nucleotide sequence on the right-hand end of each 10 oligonucleotide tag ("Tag A", "Tag B", "Tag C") is arbitrary unique sequence; that is, it is designed and synthesized to be unique to each oligonucleotide tag.

Fig. 2 is a diagram depicting a locus-specific tagged oligonucleotide. The nucleotide sequence at the left-hand end is complementary to the arbitrary sequence of one of the oligonucleotide tags depicted in Fig. 1. The nucleotide sequence at the right- 15 hand end is complementary to the amplification product of a known polymorphic locus (e.g., a single nucleotide polymorphism (SNP)). Therefore, locus-specific tagged oligonucleotide "A" comprises anucleotide sequence complementary to the arbitrary sequence of the "Tag A" oligonucleotide tag depicted in Fig. 1, and also comprises sequence complementary to SNP "A".

20 Fig. 3 is a diagram showing the hybridization of the locus-specific tagged oligonucleotide to the amplification product. The locus-specific sequence (right hand end) of the oligonucleotide is designed so that it terminates one nucleotide immediately before (5' of) the nucleotide to be genotyped (shown in box).

Fig. 4 is a diagram depicting the labeling of the locus-specific tagged 25 oligonucleotide-amplification primer complex via single base extension. During the reaction, a single labeled ddNTP complementary to the queried nucleotide is enzymatically added to the 3' end of the locus-specific tagged oligonucleotide. The nucleotide is shown in the box.

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Fig. 5 is a diagram depicting the hybridization of the complex of the amplification product and the locus-specific tagged oligonucleotide to the oligonucleotide tags on the array. The solid substrate to which the oligonucleotide tags of the array are bound is shown on the left, with the individual addresses labeled as "A", "B", etc. Each oligonucleotide tag is shown at its address. The locus-specific tagged oligonucleotide is shown hybridized to the oligonucleotide tag, and the amplification product is in turn bound to the locus-specific tagged oligonucleotide. The locus-specific tagged oligonucleotide is bound to a labeled (■, ●, etc.) nucleotide as a result of single base extension. Although a single complex is shown at each address, in reality, many such oligonucleotide tags are located at each address; that is, the substrate surface at address "A" has many copies of oligonucleotide tag "A" attached to it, etc.

Fig. 6 is a diagram depicting the hybridization as in Fig. 5, but the sample at address "B" is heterozygous for the queried nucleotide.

Fig. 7 is a schematic showing the combined use of amplification, single base extension of a tagged primer, and hybridization to a tag array.

Fig. 8 shows a quantitative measurement of allele frequency. Template-T (5'-TGCTGAATATTCA GATTCTCTAGTGCTACCTGAAAGATCCTG-3'; SEQ ID NO: 1) and Template-G (5'-TGCTGAATATTCA GATTCTCGAGTGCTACCTGAAAGATCCTG-3'; SEQ ID NO: 2) were mixed at different ratios (6 nM / 60 nM, 6 nM / 18 nM, 6 nM / 6 nM, 18 nM / 6 nM, 60 nM / 6 nM, 180 nM / 6 nM). Six SBE primers (5'-CACCATGCTACAATGAATGCAGGATTTCAGGTAGCACT-3' (SEQ ID NO: 3); 5'-GATAATTCTCTGATAAGGCCGCAGGATCTTCAGGTAGCACT-3' (SEQ ID NO: 4); 5'-GACTACGATGTGATCCGTGTCAGGATCTTCAGGTAGCACT-3' (SEQ ID NO: 5);

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5'-GAACGCAGTTATCAGACTCTCAGGATCTTCAGGTAGCACT-3' (SEQ ID NO: 6);
5'-CGAGGACATGGAGTCACATCCAGGATCTTCAGGTAGC-ACT-3' (SEQ ID NO: 7); and
5 5'-GCTAGGCATTCCCTCCAGTGTCAAGGATCTTCAGGTAGCACT-3' (SEQ ID NO: 8)) were separately added to six SBE reactions which contain the mixed templates of different ratios. The SBE primers were extended in the presence of biotin-labeled ddATP and fluorescein-labeled ddCTP (see Examples) and pooled and hybridized to the tag array. The intensity ratio of the two colors (the y-axis) were plotted against the ratio
10 of the mixed two templates (the x-axis).

Fig. 9 shows a clustering analysis of the tag array hybridization results in 44 individuals at marker GMP-140.25.

DETAILED DESCRIPTION OF THE INVENTION

The invention features a generic or universal genotyping array, consisting of
15 oligonucleotide tags attached to a solid substrate (Fig. 1). Each address in the array (e.g., "A", "B", "C", etc.) has an oligonucleotide tag associated with it. The oligonucleotide tag at a given address is attached to the solid substrate, and comprises a unique arbitrary nucleotide sequence. That is, the nucleotide sequence is unique for the oligonucleotide tag at each address, i.e., the nucleotide sequence for "tag A" is different
20 from the nucleotide sequence for all other tags in the array. The nucleotide sequence for each tag is arbitrary in that it can be any sequence, provided that it is different from the nucleotide sequence for every other tag in the array. Preferably the oligonucleotide tag is from about 20 to about 50 nucleotides in length. It may also be desirable to design the nucleotide sequence of the oligonucleotide tag such that it does not facilitate an
25 undesirable interaction, e.g., with the target nucleic acid molecule (amplified product).

The oligonucleotide array is used in conjunction with locus-specific tagged oligonucleotides. Each oligonucleotide tag in the array corresponds to a locus-specific tagged oligonucleotide. One end (the 5' end) of the locus-specific tagged

oligonucleotide comprises a nucleotide sequence complementary to the unique arbitrary sequence of its corresponding oligonucleotide tag (Fig. 2). Preferably, this sequence is from about 20 to about 30 nucleotides long. The other end (the 3' end) of the locus-specific tagged oligonucleotide is complementary to a target nucleic acid molecule

5 comprising a nucleotide to be queried, e.g., a polymorphic nucleotide. Preferably, the 3' end of locus-specific tagged oligonucleotide is synthesized such that when hybridized to the target nucleic acid molecule the locus-specific tagged oligonucleotide terminates one nucleotide 5' to the nucleotide to be queried. The portion of the locus-specific tagged oligonucleotide which hybridizes to the target nucleic acid molecule is

10 preferably from about 15 to about 30 nucleotides long. For example, the 5' end of locus-specific tagged oligonucleotide "A" would be complementary to the unique arbitrary sequence at the end of the oligonucleotide tag "A" which is bound to address "A" in the array. The 3' end of locus-specific tagged oligonucleotide "A" would be complementary to the polynucleotide sequence 5' of the nucleotide to be queried in

15 target "A".

To genotype a nucleic acid sample from an individual at locus "A", amplification primers specific for the region containing locus "A" are used to amplify the nucleic acid molecules in the sample. Locus-specific tagged oligonucleotides complementary to the nucleotide sequence 5' of locus "A" are combined with the

20 amplification products under conditions suitable for hybridization (Fig. 3). The hybridization complex is subjected to single base extension. The four types of ddNTPs in the reaction mixture have different labels (e.g., four different fluorescent tags, e.g., the ddATPs would have an attached fluorophore that fluoresced at a first wavelength, the ddCTPs would have an attached fluorophore that fluoresced at a second wavelength,

25 the ddGTPs would have an attached fluorophore that fluoresced at a third wavelength, and the ddTTPs would have an attached fluorophore that fluoresced at a fourth wavelength). During the single base extension reaction, a single ddNTP is attached (Fig. 4), resulting in the formation of a complex composed of the locus-specific tagged oligonucleotide extended with the labeled ddNTP and the amplification product.

After the single base extension reaction, the complex of the labeled (extended) locus-specific tagged oligonucleotide and the amplification product is hybridized to the array (Fig. 5). The oligonucleotide tag "A" at address "A" selectively hybridizes to its corresponding locus-specific tagged oligonucleotide (now extended with a labeled ddNTP), the oligonucleotide tag "B" at address "B" selectively hybridizes to its corresponding locus-specific tagged oligonucleotide (now extended with a labeled ddNTP), etc. The array is assayed to determine which label(s) is (are) present at which address on the array. For instance, if address "A" fluoresced at the same wavelength as the label on the ddATP, then the amplification product clearly contained a "T" at the queried nucleotide (because the single base extension reaction attaches the ddNTP complementary to the queried nucleotide). Fluorescence at a wavelength which is the same as the ddCTP label would indicate that the genotype was a "G", etc. Detection of two peaks within the wavelength emitted would indicate that different nucleotides were present at the queried position in the sample, e.g., that the individual was heterozygous at that locus.

An advantage of the array and method described herein is that many addresses can be assayed simultaneously, producing genotyping data for many different genetic loci, e.g., SNPs. By utilizing a predefined set of locus-specific tagged oligonucleotides, e.g., a set specific for assaying a set of genetic diseases, a single array can be utilized for a particular purpose, and by utilizing a different set of locus-specific tagged oligonucleotides which correspond to the same tags on the array, the same array can be utilized for a different purpose. The universal chip serves as the repository of a set of addresses to which the locus-specific tagged oligonucleotides (along with the labeled, genotyped SNPs) hybridize in a planned, predetermined manner. The array and set(s) of locus-specific tagged oligonucleotides can therefore be used as components in kits for the purposes of sequencing and genotyping. Sets of locus-specific tagged oligonucleotides can therefore be used in combination with arrays as described herein for use in forensics, identification of individuals, and disease diagnosis/prognosis.

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The present invention provides a convenient and accurate way of determining the genotype of an individual at a polymorphic locus or the frequency of alleles in a population. One embodiment of the method involves three steps: (1) amplification of a polymorphic locus. (2) primer extension of a sequence-tagged primer with distinct 5 labels for different polynucleotides at the polymorphic locus, and (3) hybridization to a tag array. The amount of each distinct label can be determined at known positions of the tag array. Each tag represents a distinct polymorphic locus and each distinct label represents a distinct allelic form at the polymorphic locus. The method permits the simultaneous determination of a genotype at multiple loci, as well as the determination 10 of allele frequencies in a population. Another embodiment employs just steps 2 and 3.

Advantages of the disclosed method include that just one generic tag array can be used to genotype any genetic marker. *i.e.*, no specific customized genotyping chip is needed. In addition, the pre-selected probe sequences synthesized on the tag chip guarantee good hybridization results between the probe and the tag. Moreover, the two 15 color or multiple color approach used in this assay provides accurate measurement of the allele frequency in the samples tested. This means very reliable genotype results can be obtained not only for individual samples, but also for pooled samples.

A pair of primers or a single primer can be used to amplify a region of a nucleic acid in a sample. The sample may be from a single individual or may be from a 20 population of individuals. The region which is amplified includes a polymorphic locus. The step of amplification is not specific for a particular allele. However, the amplification is designed to specifically amplify regions of double stranded or single stranded nucleic acids which contain polymorphic loci.

The amplification step may be carried out using any technique known in the art. 25 One preferred technique is polymerase chain reaction (PCR) in which DNA is amplified logarithmically. As is known in the art, each primer of a pair of amplification primers hybridizes to, and is preferably complementary to, opposite strands of an allele. It is preferred that the primers hybridize to a double stranded nucleic acid in locations which are not more than 2 kb apart, and preferably which are much closer together, such as not

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more than 1 kb, 0.5 kb, 0.2 kb, 0.1 kb, 0.01 kb or 0.001 kb apart. A suitable DNA polymerase can be used as is known in the art. Thermostable polymerases are particularly convenient for thermal cycling of rounds of primer hybridization, polymerization, and melting. Amplification of single stranded nucleic acids can also 5 be employed.

After the amplification it is desirable to remove and/or degrade any excess primers and nucleotides. This can be done by washing and/or enzymatic degradation, using such enzymes as endonuclease I and alkaline phosphatase, for example. Other techniques, such as chromatography, magnetic beads, and avidin- or streptavidin- 10 conjugated beads, as are known in the art for accomplishing the removal can also be used. It is not necessary to remove or destroy one of two strands of an amplified DNA product.

The primer extension step of the method is the one which provides allele-specificity to the method. The primer is designed to terminate one nucleotide 5' to the 15 polymorphic locus. The primer is hybridized to the denatured amplified double stranded DNA. When the primer is extended by a single base using dideoxynucleotides and a DNA polymerase, the dideoxynucleotide which is complementary to the nucleotide at the polymorphic locus is added. Again, any DNA-dependent DNA polymerase can be used. These include, but are not limited to, *E. coli* DNA polymerase 20 I, Klenow fragment of polymerase I, T4 DNA polymerase, T7 DNA polymerase, *T. aquaticus* DNA polymerase. This reaction is preferably performed at the T_m of the primer with the template to enhance product formation.

One configuration for carrying out the primer extension step utilizes two different primers which each hybridize to opposite strands of an amplified double 25 stranded DNA. Each primer terminates one nucleotide 5' to the polymorphic locus. The primer extension reaction may be more robust with one strand as a template than the other. In addition, the information obtained from the second strand should confirm the information obtained from the first strand.

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An alternative method for primer extension involves use of reverse transcriptase and one or two primers which hybridize 3' to the polymorphic locus. This method may be desirable in cases where "forward" direction primer extension is less robust than is desirable.

5 Each different dideoxynucleotide present in the single base extension reaction is uniquely labeled. The unique label can be detected and its amount will be proportional to the amount of the particular allele containing the corresponding deoxynucleotide in the sample. If the sample is from a single individual, the nucleotide bases present at the polymorphic locus can be determined. If the sample is from a population of individuals
10 the allele frequency in the population can be determined.

The ability to perform the method of the present invention in a multiplex manner for a number of different polymorphic loci simultaneously is due to the sequence tags which are present on the extension primers at their 5' ends. The sequence tags permit the method operator to ultimately sort the products of multiplex amplification and
15 multiplex primer base extension to different locations on an array. Each sequence tag on an extension primer is used only for a single polymorphic locus. Thus the products of primer extension reactions can be separately analyzed because they can be hybridized to distinct known locations on an array.

The sequence tags are typically totally unrelated to the sequences of the
20 polymorphic alleles which are being analyzed. The sequence tags are chosen for their favorable hybridization characteristics. The tags are typically selected so that they have similar hybridization characteristics and minimal cross-hybridization to other tag sequences. Each sequence tag is attached to a specific gene or genetic marker, and then serves as a label for that particular gene or genetic marker. A generic tag array,
25 corresponding to the pre-selected tag sequences is fabricated and used to detect the presence or absence or ratio of specific allelic forms in a test sample. See application Serial No. 08/626,285 filed April 4, 1996, and EP application no. 97302313.8 which are expressly incorporated by reference herein.

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The labels which are used can be any which are known in the art. These include radiolabels, fluorescent labels, enzyme labels, epitope labels, and high affinity binding partner labels. Examples include isotopically labeled nucleotides, fluorescein-labeled nucleotides, biotin-labeled nucleotides, digoxin labeled nucleotides. A different label is 5 assigned to each base dideoxynucleotide in the single base extension reaction. Two, three, or four different labels can be used in the reaction. The different labels can be all of the same type, *e.g.*, enzyme labels, or they can be mixed types.

Hybridization of the 5' portion of the extension primers (the tag sequences) to one or more probes which are immobilized to known locations on a solid support is also 10 contemplated. Hybridization can be performed under standard conditions known in the art for obtaining robust signals at high specificity. Standard washing conditions can also be employed. Detection of hybridization of the extension primers can be done using standard means, depending on the type of labels used. For example, fluorescence can be detected and quantified using optical detection means. Radiolabels can be 15 detected using autoradiography or scintillation counting. Enzyme labels can be detected using enzymatic reactions and assaying for the final product of the enzyme reaction. Antigenic labels can be used using immunological detection means. Affinity binding partners such as strepavidin or avidin and biotin can also be used as a label.

The reactions of the present invention can be performed in a single or multiplex 20 format. For example, the amplification step can be performed using up to 20, 30, 40, 50, 75, 100, 150, 200, 250, or 300 different primer pairs to amplify a corresponding number of polymorphic markers. These can be pooled for the single base extension reaction, if desired. Pooling for the hybridization step is desirable so that thousands of hybridizations can be done simultaneously.

25 In an alternative embodiment the amplification step can be omitted. Thus, if sufficient DNA is available, the single base extension reaction can be performed directly on genomic DNA. In another particular embodiment, amplification of the entire genome can be performed using random primers.

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Sets of primers according to the present invention comprise an amplification pair and an extension primer. These are used together in a method for determining a ratio of nucleotides present at a polymorphic locus. These may be packaged in a single container, preferably a divided container or package. The pair of primers amplify a 5 region of double stranded DNA which comprises a polymorphic locus. The extension primer has two portions, a 3' portion which is complementary to a portion of the region of double stranded DNA which contains the polymorphic locus and a 5' portion which is not complementary to the region of double stranded DNA. The 5' region is the tag sequence which is complementary to the tag array which is used to sort and analyze the 10 products of the single base extension reaction. The 3' end of the single base extension primer terminates one nucleotide 5' to the polymorphic locus.

Kits according to the present invention may contain one or more sets of primers as described above. The kit may also contain a solid support comprising at least one probe which is attached to the solid support. The one or more probes are 15 complementary to the 5' portion of the extension primer, *i.e.*, to the tag sequences. Solid supports, according to the present invention include beads, microtiter plates, and arrays.

Hybridizing Nucleic Acids to Arrays of Allele-Specific Probes

“Hybridization” refers to the formation of a bimolecular complex of two 20 different nucleic acids through complementary base pairing. Complementary base pairing occurs through non-covalent bonding, usually hydrogen bonding, of bases that specifically recognize other bases, as in the bonding of complementary bases in double-stranded DNA. In this invention, hybridization is carried out between a target nucleic acid, which is prepared from the nucleic acid sample by allele-specific amplification, 25 and at least two probes which have been immobilized on a substrate to form an array.

One of skill in the art will appreciate that an enormous number of array designs are suitable for the practice of this invention. An array will typically include a number of probes that specifically hybridize to the sequences of interest (tags). In addition, it is

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preferred that the array include one or more control probes. In one embodiment, the array is a high density array. A high density array is an array used to hybridize with a target nucleic acid sample to detect the presence of a large number of allelic markers, preferably more than 10, more preferably more than 100, and most preferably more than 5 1000 allelic markers.

High density arrays are suitable for quantifying small variations in the frequency of an allelic marker in the presence of a large population of heterogeneous nucleic acids. Such high density arrays can be fabricated either by *de novo* synthesis on a substrate or by spotting or transporting nucleic acid sequences onto specific locations of a substrate. 10 Both of these methods produce nucleic acids which are immobilized on the array at particular locations. Nucleic acids can be purified and/or isolated from biological materials, such as a bacterial plasmid containing a cloned segment of a sequence of interest. Suitable nucleic acids can also be produced by amplification of templates or by synthesis. As a nonlimiting illustration, polymerase chain reaction and/or *in vitro* 15 transcription, are suitable nucleic acid amplification methods.

The term "target nucleic acid" refers to a nucleic acid (either synthetic or derived from a biological sample or nucleic acid sample), to which the probe is designed to specifically hybridize. In this invention, such target nucleic acids are the same as the sequence tags. It is either the presence or absence of the target nucleic acid that is to be 20 detected, or the amount of the target nucleic acid that is to be quantified. The target nucleic acid has a sequence that is complementary to the nucleic acid sequence of the corresponding probe directed to the target. The term "target nucleic acid" can refer to the specific subsequence of a larger nucleic acid to which the probe is directed or to the overall sequence (*e.g.*, gene or mRNA) whose presence it is desired to detect. The 25 difference in usage will be apparent from context.

As used herein a "probe" is defined as a nucleic acid, capable of binding to a target nucleic acid of complementary sequence through one or more types of chemical bonds, usually through complementary base pairing, usually through hydrogen bond formation. As used herein, a probe can include natural (*i.e.* A, G, U, C, or T) or

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modified bases (e.g., 7-deazaguanosine, inosine, etc.). A probe can also include an oligonucleotide. An oligonucleotide is a single-stranded nucleic acid of 2 to n bases, where n can be any integer less than 1000. Nucleic acids can be cloned or synthesized using any technique known in the art. They can also include non-naturally occurring 5 nucleotide analogs, such as those which are modified to improve hybridization, and peptide nucleic acids. In addition, the bases in probes may be joined by a linkage other than a phosphodiester bond, so long as it does not interfere with hybridization. Thus, probes may be peptide nucleic acids in which the constituent bases are joined by peptide bonds rather than phosphodiester linkages.

10 Probe Design

An array includes "test probes", also termed "oligonucleotide tags" herein. Test probes can be oligonucleotides that range from about 5 to about 45 or 5 to about 500 nucleotides, more preferably from about 10 to about 40 nucleotides and most preferably from about 15 to about 40 nucleotides in length. In other particularly preferred 15 embodiments the probes are 20 to 25 nucleotides in length. In another embodiment, test probes are double or single stranded DNA sequences. DNA sequences can be isolated or cloned from natural sources or amplified from natural sources using natural nucleic acids as templates. However, *in situ* synthesis of probes on the arrays is preferred. The probes have sequences complementary to particular subsequences of the 20 genes whose allelic markers they are designed to detect. Thus, the test probes are capable of specifically hybridizing to the target nucleic acid they are designed to detect.

The term "perfect match probe" refers to a probe which has a sequence designed to be perfectly complementary to a particular target sequence. The probe is typically perfectly complementary to a portion (subsequence) of the target sequence. The perfect 25 match probe can be a "test probe," a "normalization control probe," an expression level control probe and the like. A perfect match control or perfect match probe is, however, distinguished from a "mismatch control" or "mismatch probe" or "mismatch control probe."

In addition to test probes that bind the target nucleic acid(s) of interest, the high density array can contain a number of control probes. The control probes fall into two categories: normalization controls and mismatch controls.

Normalization controls are oligonucleotide or other nucleic acid probes that are 5 complementary to labeled reference oligonucleotides or other nucleic acid sequences that are added to the nucleic acid sample. The signals obtained from the normalization controls after hybridization provide a control for variations in hybridization conditions, label intensity, "reading" efficiency, and other factors that may cause the signal of a perfect hybridization to vary between arrays. In a preferred embodiment, signals (e.g., 10 fluorescence intensity) read from all other probes in the array are divided by the signal (e.g., fluorescence intensity) from the control probes, thereby normalizing the measurements.

Virtually any probe can serve as a normalization control. However, it is recognized that hybridization efficiency varies with base composition and probe length. 15 Preferred normalization probes are selected to reflect the average length of the other probes present in the array; however, they can be selected to cover a range of lengths. The normalization control(s) can also be selected to reflect the (average) base composition of the other probes in the array; however in a preferred embodiment, only one or a few normalization probes are used and they are selected such that they 20 hybridize well (*i.e.* no secondary structure) and do not match any target-specific probes.

Mismatch controls can also be provided for the probes to the target alleles or for normalization controls. The terms "mismatch control" or "mismatch probe" or "mismatch control probe" refer to a probe whose sequence is deliberately selected not to be perfectly complementary to a particular target sequence. Mismatch controls are 25 oligonucleotide probes or other nucleic acid probes identical to their corresponding test or control probes except for the presence of one or more mismatched bases. A mismatched base is a base selected so that it is not complementary to the corresponding base in the target sequence to which the probe would otherwise specifically hybridize. One or more mismatches are selected such that under appropriate hybridization

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conditions (e.g., stringent conditions) the test or control probe would be expected to hybridize with its target sequence, but the mismatch probe would not hybridize (or would hybridize to a significantly lesser extent). Preferred mismatch probes contain a central mismatch. Thus, for example, where a probe is a 20 mer, a corresponding mismatch probe will have the identical sequence except for a single base mismatch (e.g., substituting a G, a C, or a T for an A) at any of positions 6 through 14 (the central mismatch).

For each mismatch control in a high-density array there typically exists a corresponding perfect match probe that is perfectly complementary to the same 10 particular target sequence. The mismatch may comprise one or more bases. While the mismatch(s) may be located anywhere in the mismatch probe, terminal mismatches are less desirable, as a terminal mismatch is less likely to prevent hybridization of the target sequence. In a particularly preferred embodiment, the mismatch is located at or near the center of the probe such that the mismatch is most likely to destabilize the duplex with 15 the target sequence under the test hybridization conditions.

Mismatch probes provide a control for non-specific binding or cross-hybridization to a nucleic acid in the sample other than the target to which the probe is directed. Mismatch probes thus indicate whether or not a hybridization is specific. For 20 example, if the target is present, the perfect match probes should be consistently brighter than the mismatch probes. The difference in intensity between the perfect match and the mismatch probe ($I_{(PM)}-I_{(MM)}$) provides a good measure of the concentration of the hybridized material.

The array can also include sample preparation/amplification control probes. These are probes that are complementary to subsequences of control genes selected 25 because they do not normally occur in the nucleic acids of the particular biological sample being assayed. Suitable sample preparation/amplification control probes include, for example, probes to bacterial genes (e.g., Bio B) where the sample in question is from a eukaryote.

In a preferred embodiment, oligonucleotide probes in the high density array are selected to bind specifically to the nucleic acid target to which they are directed with minimal non-specific binding or cross-hybridization under the particular hybridization conditions utilized. Because the high density arrays of this invention can contain in 5 excess of 100,000 or even 1,000,000 different probes, it is possible to provide every probe of a characteristic length that binds to a particular nucleic acid sequence.

Forming High Density Arrays

High density arrays are particularly useful for monitoring the presence of allelic markers. The fabrication and application of high density arrays in gene expression 10 monitoring have been disclosed previously in, for example, WO 97/10365, WO 92/10588, U.S. Application Ser. No. 08/772,376 filed December 23, 1996; serial number 08/529,115 filed on September 15, 1995; serial number 08/168,904 filed December 15, 1993; serial number 07/624,114 filed on December 6, 1990, serial number 07/362,901 filed June 7, 1990, and in U.S. 5,677,195, all incorporated herein for 15 all purposes by reference. In some embodiments using high density arrays, high density oligonucleotide arrays are synthesized using methods such as the Very Large Scale Immobilized Polymer Synthesis (VLSIPS) disclosed in U.S. Pat. No. 5,445,934 incorporated herein for all purposes by reference. Each oligonucleotide occupies a known location on a substrate. A nucleic acid target sample is hybridized with a high 20 density array of oligonucleotides and then the amount of target nucleic acids hybridized to each probe in the array is quantified.

Synthesized oligonucleotide arrays are particularly preferred for this invention. Oligonucleotide arrays have numerous advantages over other methods, such as 25 efficiency of production, reduced intra- and inter array variability, increased information content, and high signal-to-noise ratio.

Preferred high density arrays comprise greater than about 100, preferably greater than about 1000, more preferably greater than about 16,000, and most preferably greater than 65,000 or 250,000 or even greater than about 1,000,000 different oligonucleotide

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probes, preferably in less than 1 cm² of surface area. The oligonucleotide probes range from about 5 to about 50 or about 500 nucleotides, more preferably from about 10 to about 40 nucleotides, and most preferably from about 15 to about 40 nucleotides in length.

5 Methods of forming high density arrays of oligonucleotides, peptides and other polymer sequences with a minimal number of synthetic steps are known. The oligonucleotide analogue array can be synthesized on a solid substrate by a variety of methods, including, but not limited to, light-directed chemical coupling and mechanically directed coupling. See Pirtung *et al.*, U.S. Patent No. 5,143,854 (see also
10 PCT Application No. WO 90/15070) and Fodor *et al.*, PCT Publication Nos. WO 92/10092 and WO 93/09668 and U.S. Ser. No. 07/980,523, which disclose methods of forming vast arrays of peptides, oligonucleotides and other molecules using, for example, light-directed synthesis techniques. See also, Fodor *et al.*, *Science*, 251, 767-77 (1991). These procedures for synthesis of polymer arrays are now referred to as
15 VLSIPSTM procedures. Using the VLSIPSTM approach, one heterogeneous array of polymers is converted, through simultaneous coupling at a number of reaction sites, into a different heterogeneous array. See, U.S. Application Serial Nos. 07/796,243 and 07/980,523.

20 The development of VLSIPSTM technology as described in the above-noted U.S. Patent No. 5,143,854 and PCT patent publication Nos. WO 90/15070 and 92/10092, is considered pioneering technology in the fields of combinatorial synthesis and screening of combinatorial libraries. More recently, patent application Serial No. 08/082,937, filed June 25, 1993, describes methods for making arrays of oligonucleotide probes that can be used to check or determine a partial or complete sequence of a target nucleic acid
25 and to detect the presence of a nucleic acid containing a specific oligonucleotide sequence.

In brief, the light-directed combinatorial synthesis of oligonucleotide arrays on a glass surface proceeds using automated phosphoramidite chemistry and chip masking techniques. In one specific implementation, a glass surface is derivatized with a silane

reagent containing a functional group, *e.g.*, a hydroxyl or amine group blocked by a photolabile protecting group. Photolysis through a photolithographic mask is used selectively to expose functional groups which are then ready to react with incoming 5'-photoprotected nucleoside phosphoramidites. The phosphoramidites react only with 5 those sites which are illuminated (and thus exposed by removal of the photolabile blocking group). Thus, the phosphoramidites only add to those areas selectively exposed from the preceding step. These steps are repeated until the desired array of sequences have been synthesized on the solid surface. Combinatorial synthesis of 10 different oligonucleotide analogues at different locations on the array is determined by the pattern of illumination during synthesis and the order of addition of coupling 15 reagents.

In the event that an oligonucleotide analogue with a polyamide backbone is used in the VLSIPS™ procedure, it is generally inappropriate to use phosphoramidite chemistry to perform the synthetic steps, since the monomers do not attach to one 15 another via a phosphate linkage. Instead, peptide synthetic methods are substituted. See, *e.g.*, Pirrung *et al.* U.S. Pat. No. 5,143,854.

Peptide nucleic acids are commercially available from, *e.g.*, Biosearch, Inc. (Bedford, MA) which comprise a polyamide backbone and the bases found in naturally occurring nucleosides. Peptide nucleic acids are capable of binding to nucleic acids 20 with high specificity, and are considered "oligonucleotide analogues" for purposes of this disclosure.

Additional methods which can be used to generate an array of oligonucleotides on a single substrate are described in co-pending Applications Ser. No. 07/980,523, filed November 20, 1992, and 07/796,243, filed November 22, 1991 and in PCT 25 Publication No. WO 93/09668. In the methods disclosed in these applications, reagents are delivered to the substrate by either (1) flowing within a channel defined on predefined regions or (2) "spotting" on predefined regions or (3) through the use of photoresist. However, other approaches, as well as combinations of spotting and flowing, can be employed. In each instance, certain activated regions of the substrate

are mechanically separated from other regions when the monomer solutions are delivered to the various reaction sites.

A typical "flow channel" method applied to the compounds and libraries of the present invention can generally be described as follows. Diverse polymer sequences are 5 synthesized at selected regions of a substrate or solid support by forming flow channels on a surface of the substrate through which appropriate reagents flow or in which appropriate reagents are placed. For example, assume a monomer "A" is to be bound to the substrate in a first group of selected regions. If necessary, all or part of the surface of the substrate in all or a part of the selected regions is activated for binding by, for 10 example, flowing appropriate reagents through all or some of the channels, or by washing the entire substrate with appropriate reagents. After placement of a channel block on the surface of the substrate, a reagent having the monomer A flows through or is placed in all or some of the channel(s). The channels provide fluid contact to the first selected regions, thereby binding the monomer A on the substrate directly or indirectly 15 (via a spacer) in the first selected regions.

Thereafter, a monomer "B" is coupled to second selected regions, some of which can be included among the first selected regions. The second selected regions will be in fluid contact with a second flow channel(s) through translation, rotation, or replacement of the channel block on the surface of the substrate; through opening or closing a 20 selected valve; or through deposition of a layer of chemical or photoresist. If necessary, a step is performed for activating at least the second regions. Thereafter, the monomer B is flowed through or placed in the second flow channel(s), binding monomer B at the second selected locations. In this particular example, the resulting sequences bound to the substrate at this stage of processing will be, for example, A, B, and AB. The process 25 is repeated to form a vast array of sequences of desired length at known locations on the substrate.

After the substrate is activated, monomer A can be flowed through some of the channels, monomer B can be flowed through other channels, a monomer C can be flowed through still other channels, *etc.* In this manner, many or all of the reaction

regions are reacted with a monomer before the channel block must be moved or the substrate must be washed and/or reactivated. By making use of many or all of the available reaction regions simultaneously, the number of washing and activation steps can be minimized.

5 One of skill in the art will recognize that there are alternative methods of forming channels or otherwise protecting a portion of the surface of the substrate. For example, according to some embodiments, a protective coating such as a hydrophilic or hydrophobic coating (depending upon the nature of the solvent) is utilized over portions of the substrate to be protected, sometimes in combination with materials that facilitate 10 wetting by the reactant solution in other regions. In this manner, the flowing solutions are further prevented from passing outside of their designated flow paths.

High density nucleic acid arrays can be fabricated by depositing presynthesized or natural nucleic acids in predetermined positions. Synthesized or natural nucleic acids are deposited on specific locations of a substrate by light directed targeting and 15 oligonucleotide directed targeting. Nucleic acids can also be directed to specific locations in much the same manner as the flow channel methods. For example, a nucleic acid A can be delivered to and coupled with a first group of reaction regions which have been appropriately activated. Thereafter, a nucleic acid B can be delivered to and reacted with a second group of activated reaction regions. Nucleic acids are 20 deposited in selected regions. Another embodiment uses a dispenser that moves from region to region to deposit nucleic acids in specific spots. Typical dispensers include a micropipette or capillary pin to deliver nucleic acid to the substrate and a robotic system to control the position of the micropipette with respect to the substrate. In other embodiments, the dispenser includes a series of tubes, a manifold, an array of pipettes 25 or capillary pins, or the like so that various reagents can be delivered to the reaction regions simultaneously.

Hybridization Conditions

The term "stringent conditions" refers to conditions under which a probe will hybridize to its target subsequence, but with only insubstantial hybridization to other sequences or to other sequences such that the difference may be identified. Stringent 5 conditions are sequence-dependent and will be different in different circumstances. Longer sequences hybridize specifically at higher temperatures. Generally, stringent conditions are selected to be about 5°C lower than the thermal melting point (T_m) for the specific sequence at a defined ionic strength and pH.

The T_m is the temperature, under defined ionic strength, pH, and nucleic acid 10 concentration, at which 50% of the probes complementary to the target sequence hybridize to the target sequence at equilibrium. As the target sequences are generally present in excess, at T_m , 50% of the probes are occupied at equilibrium. Typically, stringent conditions will be those in which the salt concentration is at least about 0.01 to 1.0 M concentration of a Na or other salt at pH 7.0 to 8.3 and the temperature is at least 15 about 30°C for short probes (e.g., 10 to 50 nucleotides). Stringent conditions can also be achieved with the addition of destabilizing agents such as formamide.

The phrase "hybridizing specifically to" refers to the binding, duplexing, or hybridizing of a molecule substantially to or only to a particular nucleotide sequence or sequences under stringent conditions when that sequence is present in a complex 20 mixture (e.g., total cellular) of DNA or RNA. It is generally recognized that nucleic acids are denatured by increasing the temperature or decreasing the salt concentration of the buffer containing the nucleic acids. Under low stringency conditions (e.g., low temperature and/or high salt) hybrid duplexes (e.g., DNA:DNA, RNA:RNA, or RNA:DNA) will form even where the annealed sequences are not perfectly 25 complementary. Thus, specificity of hybridization is reduced at lower stringency. Conversely, at higher stringency (e.g., higher temperature or lower salt) successful hybridization requires fewer mismatches.

One of skill in the art will appreciate that hybridization conditions can be selected to provide any degree of stringency. In a preferred embodiment, hybridization

is performed at low stringency, in this case in 6X SSPE-T at 37°C (0.005% Triton X-100), to ensure hybridization, and then subsequent washes are performed at higher stringency (e.g., 1 X SSPE-T at 37°C) to eliminate mismatched hybrid duplexes.

Successive washes can be performed at increasingly higher stringency (e.g., down to as low as 0.25 X SSPE-T at 37°C to 50°C) until a desired level of hybridization specificity is obtained. Stringency can also be increased by addition of agents such as formamide. Hybridization specificity can be evaluated by comparison of hybridization to the test probes with hybridization to the various controls that can be present (e.g., expression level control, normalization control, mismatch controls, etc.).

In general, there is a tradeoff between hybridization specificity (stringency) and signal intensity. Thus, in a preferred embodiment, the wash is performed at the highest stringency that produces consistent results and that provides a signal intensity greater than approximately 10% of the background intensity. Thus, in a preferred embodiment, the hybridized array can be washed at successively higher stringency solutions and read between each wash. Analysis of the data sets thus produced will reveal a wash stringency above which the hybridization pattern is not appreciably altered and which provides adequate signal for the particular oligonucleotide probes of interest.

The stability of duplexes formed between RNAs or DNAs are generally in the order of RNA:RNA > RNA:DNA > DNA:DNA, in solution. Long probes have better duplex stability with a target, but poorer mismatch discrimination than shorter probes (mismatch discrimination refers to the measured hybridization signal ratio between a perfect match probe and a single base mismatch probe). Shorter probes (e.g., 8-mers) discriminate mismatches very well, but the overall duplex stability is low.

Altering the thermal stability (T_m) of the duplex formed between the target and the probe using, e.g., known oligonucleotide analogues allows for optimization of duplex stability and mismatch discrimination. One useful aspect of altering the T_m arises from the fact that adenine-thymine (A-T) duplexes have a lower T_m than guanine-cytosine (G-C) duplexes, due in part to the fact that the A-T duplexes have two hydrogen bonds per base-pair, while the G-C duplexes have three hydrogen bonds per

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base pair. In heterogeneous oligonucleotide arrays in which there is a non-uniform distribution of bases, it is not generally possible to optimize hybridization for each oligonucleotide probe simultaneously. Thus, in some embodiments, it is desirable to selectively destabilize G-C duplexes and/or to increase the stability of A-T duplexes.

5 This can be accomplished, *e.g.*, by substituting guanine residues in the probes of an array which form G-C duplexes with hypoxanthine, or by substituting adenine residues in probes which form A-T duplexes with 2,6 diaminopurine or by using tetramethyl ammonium chloride (TMACl) in place of NaCl.

Altered duplex stability conferred by using oligonucleotide analogue probes can 10 be ascertained by following, *e.g.*, fluorescence signal intensity of oligonucleotide analogue arrays hybridized with a target oligonucleotide over time. The data allow optimization of specific hybridization conditions at, *e.g.*, room temperature.

Another way of verifying altered duplex stability is by following the signal 15 intensity generated upon hybridization with time. Previous experiments using DNA targets and DNA chips have shown that signal intensity increases with time, and that the more stable duplexes generate higher signal intensities faster than less stable duplexes. The signals reach a plateau or "saturate" after a certain amount of time due to all of the binding sites becoming occupied. These data allow for optimization of hybridization, and determination of the best conditions at a specified temperature.

20 Methods of optimizing hybridization conditions are well known to those of skill in the art (*see, e.g.*, *Laboratory Techniques in Biochemistry and Molecular Biology, Vol. 24: Hybridization With Nucleic Acid Probes*, P. Tijssen, ed. Elsevier, N.Y., (1993)).

Signal Detection

25 The hybridized nucleic acids can be detected by detecting one or more labels attached to the target nucleic acids. The labels can be incorporated by any of a number of means well known to those of skill in the art. However, in a preferred embodiment, the label is incorporated by labeling the primers prior to the amplification step in the

preparation of the target nucleic acids. Thus, for example, polymerase chain reaction with labeled primers will provide a labeled amplification product.

Detectable labels suitable for use in the present invention include any composition detectable by spectroscopic, photochemical, biochemical, 5 immunochemical, electrical, optical, or chemical means. Useful labels in the present invention include biotin for staining with labeled streptavidin conjugate, magnetic beads (e.g., DynabeadsTM), fluorescent dyes (e.g., fluorescein, texas red, rhodamine, green fluorescent protein, and the like), radiolabels (e.g., ³H, ¹²⁵I, ³⁵S, ¹⁴C, or ³²P), enzymes (e.g., horseradish peroxidase, alkaline phosphatase and others commonly used in an 10 ELISA), and colorimetric labels such as colloidal gold or colored glass or plastic (e.g., polystyrene, polypropylene, latex, etc.) beads. Patents teaching the use of such labels include U.S. Patent Nos. 3,817,837; 3,850,752; 3,939,350; 3,996,345; 4,277,437; 4,275,149; and 4,366,241.

Means of detecting such labels are well known to those of skill in the art. Thus, 15 for example, radiolabels can be detected using photographic film or scintillation counters, fluorescent markers can be detected using a photodetector to detect emitted light. Enzymatic labels are typically detected by providing the enzyme with a substrate and detecting the reaction product produced by the action of the enzyme on the substrate, and colorimetric labels are detected by simply visualizing the colored label. 20 One method uses colloidal gold label that can be detected by measuring scattered light.

Means of detecting labeled target nucleic acids hybridized to the probes of the array are known to those of skill in the art. Thus, for example, where a colorimetric label is used, simple visualization of the label is sufficient. Where a radioactive labeled probe is used, detection of the radiation (e.g. with photographic film or a solid state 25 detector) is sufficient.

Detection of target nucleic acids which are labeled with a fluorescent label (*i.e.*, a "color tag") can be accomplished with fluorescence microscopy. The hybridized array can be excited with a light source at the excitation wavelength of the particular fluorescent label and the resulting fluorescence at the emission wavelength is detected.

The excitation light source can be a laser appropriate for the excitation of the fluorescent label.

The confocal microscope can be automated with a computer-controlled stage to automatically scan the entire high density array, *i.e.*, to sequentially examine individual probes or adjacent groups of probes in a systematic manner until all probes have been examined. Similarly, the microscope can be equipped with a phototransducer (*e.g.*, a photomultiplier, a solid state array, a CCD camera, *etc.*) attached to an automated data acquisition system to automatically record the fluorescence signal produced by hybridization to each oligonucleotide probe on the array. Such automated systems are described at length in U.S. Patent No: 5,143,854, PCT Application 20 92/10092, and copending U.S. Application Ser. No. 08/195,889, filed on February 10, 1994. Use of laser illumination in conjunction with automated confocal microscopy for signal detection permits detection at a resolution of better than about 100 μm , more preferably better than about 50 μm , and most preferably better than about 25 μm .

Two different fluorescent labels can be used in order to distinguish two alleles at each marker examined. In such a case, the array can be scanned two times. During the first scan, the excitation and emission wavelengths are set as required to detect one of the two fluorescent labels. For the second scan, the excitation and emission wavelengths are set as required to detect the second fluorescent label. When the results from both scans are compared, the genotype identification or allele frequency can be determined.

Quantification and Determination of Genotypes

The term "quantifying" when used in the context of quantifying hybridization of a nucleic acid sequence or subsequence can refer to absolute or to relative quantification. Absolute quantification can be accomplished by inclusion of known concentration(s) of one or more target nucleic acids (*e.g.*, control nucleic acids such as Bio B, or known amounts the target nucleic acids themselves) and referencing the hybridization intensity of unknowns with the known target nucleic acids (*e.g.*, through

generation of a standard curve). Alternatively, relative quantification can be accomplished by comparison of hybridization signals between two or more genes, or between two or more treatments to quantify the changes in hybridization intensity and, by implication, the frequency of an allele. Relative quantification can also be used to 5 merely detect the presence or absence of an allele in the target nucleic acids. In one embodiment, for example, the presence or absence of the two alleles of a marker can be determined by comparing the quantities of the first and second color tag at the known locations in the array, *i.e.*, on the solid support, which correspond to the allele-specific probes for the two alleles.

10 A preferred quantifying method is to use a confocal microscope and fluorescent labels. The GeneChip® system (Affymetrix, Santa Clara, CA) is particularly suitable for quantifying the hybridization; however, it will be apparent to those of skill in the art that any similar system or other effectively equivalent detection method can also be used.

15 Methods for evaluating the hybridization results vary with the nature of the specific probes used, as well as the controls. Simple quantification of the fluorescence intensity for each probe can be determined. This can be accomplished simply by measuring signal strength at each location (representing a different probe) on the high density array (*e.g.*, where the label is a fluorescent label, detection of the fluorescence 20 intensity produced by a fixed excitation illumination at each location on the array).

One of skill in the art, however, will appreciate that hybridization signals will vary in strength with efficiency of hybridization, the amount of label on the sample nucleic acid and the amount of the particular nucleic acid in the sample. Typically nucleic acids present at very low levels (*e.g.*, < 1 pM) will show a very weak signal. At 25 some low level of concentration, the signal becomes virtually indistinguishable from background. In evaluating the hybridization data, a threshold intensity value can be selected below which a signal is counted as being essentially indistinguishable from background.

The terms "background" or "background signal intensity" refer to hybridization signals resulting from non-specific binding, or other interactions, between the labeled target nucleic acids and components of the oligonucleotide array (e.g., the oligonucleotide probes, control probes, the array substrate, *etc.*). Background signals 5 may also be produced by intrinsic fluorescence of the array components themselves. A single background signal can be calculated for the entire array, or a different background signal may be calculated for each target nucleic acid. In a preferred embodiment, background is calculated as the average hybridization signal intensity for the lowest 5% to 10% of the probes in the array, or, where a different background signal 10 is calculated for each target allele, for the lowest 5% to 10% of the probes for each allele. However, where the probes to a particular allele hybridize well and thus appear to be specifically binding to a target sequence, they should not be used in a background signal calculation. Alternatively, background may be calculated as the average hybridization signal intensity produced by hybridization to probes that are not 15 complementary to any sequence found in the sample (e.g., probes directed to nucleic acids of the opposite sense or to genes not found in the sample, such as bacterial genes where the sample is mammalian nucleic acids). Background can also be calculated as the average signal intensity produced by regions of the array that lack any probes at all. In a preferred embodiment, background signal is reduced by the use of a detergent (e.g., 20 C-TAB) or a blocking reagent (e.g., sperm DNA, cot-1 DNA, *etc.*) during the hybridization to reduce non-specific binding. In a particularly preferred embodiment, the hybridization is performed in the presence of about 0.5 mg/ml DNA (e.g., herring sperm DNA). The use of blocking agents in hybridization is well known to those of skill in the art (*see, e.g.*, Chapter 8 in P. Tijssen, *supra*).

25 The high density array can include mismatch controls. In a preferred embodiment, there is a mismatch control having a central mismatch for every probe in the array, except the normalization controls. It is expected that after washing in stringent conditions, where a perfect match would be expected to hybridize to the probe, but not to the mismatch, the signal from the mismatch controls should only reflect non-

specific binding or the presence in the sample of a nucleic acid that hybridizes with the mismatch. Where both the probe in question and its corresponding mismatch control show high signals, or the mismatch shows a higher signal than its corresponding test probe, there is a problem with the hybridization and the signal from those probes is ignored. For a given marker, the difference in hybridization signal intensity ($I_{allele1} - I_{allele2}$) between an allele-specific probe (perfect match probe) for a first allele and the corresponding probe for a second allele (or other mismatch control probe) is a measure of the presence of or concentration of the first allele. Thus, in a preferred embodiment, the signal of the mismatch probe is subtracted from the signal for its corresponding test probe to provide a measure of the signal due to specific binding of the test probe.

The concentration of a particular sequence can then be determined by measuring the signal intensity of each of the probes that bind specifically to that gene and normalizing to the normalization controls. Where the signal from the probes is greater than the mismatch, the mismatch is subtracted. Where the mismatch intensity is equal to or greater than its corresponding test probe, the signal is ignored (*i.e.*, the signal cannot be evaluated).

For each marker analyzed, the genotype can be unambiguously determined by comparing the hybridization patterns obtained for each of the two labels, *e.g.*, color tags employed (Fig. 8). If hybridization is indicated for one color tag to its corresponding allele-specific probe (*e.g.*, "A") but not for the other color tag (*e.g.*, "G") (pattern at left in Fig. 8), then the indicated genotype of a diploid organism would be homozygous A/A. If hybridization is indicated only for the other color tag to its corresponding allele-specific probe (*e.g.*, "G") (pattern at center in Fig. 8), then the indicated genotype of a diploid organism would be homozygous G/G. If hybridization is indicated for both color tags to their corresponding allele-specific probes (pattern at right in Fig. 8), then the indicated genotype of a diploid organism would be heterozygous (A/G).

Marginal detection of hybridization, indicated by an intermediate positive result (*e.g.*, less than 1%, or from 1-5%, or from 1-10%, or from 2-10%, or from 5-10%, or from 1-20%, or from 2-20%, or from 5-20%, or from 10-20% of the average of all

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positive hybridization results obtained for the entire array) may indicate either cross-hybridization or cross-amplification, depending on the overall hybridization pattern as indicated in Fig. 8. However, these can be distinguished by the unique pattern observed. Further procedures for data analysis are disclosed in U.S. Application

5 08/772,376, previously incorporated for all purposes.

HuSNP and other marker-specific arrays have been designed and used in genetic studies⁹⁻¹⁰. But the method developed in this study provides several advantages in dealing with many different genetic applications: (1) arrays based on a single generic design can be used to genotype different sets of genetic markers because no specific 10 customized genotyping array is needed; (2) the pre-selected probe sequences synthesized on the tag array help ensure good hybridization results; (3) accurate quantitative measurement of the allele frequency in the tested samples can be achieved. Thus, reliable genotype results can be obtained not only for individual samples, but also for pooled samples. Besides SBE, other assays can be coupled with tag array assay, for 15 example, oligonucleotide ligation assay (OLA)¹⁹⁻²¹, invasive cleavage of oligonucleotide probes assay²², allele specific PCR²³⁻²⁴.

Our current tag chip contains over 32,000 unique tag probes. For most of the genetic application, for example, detecting mutations in one particular gene, it doesn't need such high-density chip. Therefore, smaller chips with fewer tags on the chip are 20 sought after. Alternatively, multiple tags corresponding to one particular marker can be designed as to build the redundancy to the assay to assure accurate genotyping. Or multiple sets of tags for one set of SNPs can be designed, thus multiple samples can be processed and analyzed with one chip. Our current assay uses a two-color labeling scheme. But a four-color labeling/scanning system should warrant the assay can be done 25 in a single tube reaction.

For broader genetic applications, for example, a study needs to genotype 100s to 1000s genetic markers, amplifying the genetic loci with multiplexing PCR is still the best strategy. However, to genotype 1000s to 10,000s markers, pre-amplification of the interested genetic loci will be very labor-intensive and costly. A whole-genome

approach should be explored, for example, strategies involved using total human genomic DNA directly, or genomic DNA amplified using some general amplification methods, *e.g.*, primer-extension preamplification, PEP²⁵, or total cDNA. In fact, we have tried to use total human genomic DNA directly as the SBE template in our tag array assay. 5 24 out of the 38 of the markers that we tested gave good signals (data not shown). Nevertheless, large amount of work are warranted as to solve both the sensitivity (signal intensity) and specificity (mis-priming) problems before the whole-genome approach become really useful.

The invention will be further illustrated by the following non-limiting examples.
10 10 The content of references cited herein is incorporated herein by reference in its entirety.

EXEMPLIFICATION

METHODS

Collection and Isolation of DNA From Samples

DNA samples were collected by GenNet as part of the ongoing Family Blood Pressure Program. Samples were collected with consent and IRB approval in both Tecumseh, MI and Loyola, IL FAMILIES. Ascertainment was based on identification of a proband in the top 15th (Tecumseh) or 20th (Loyola) percentile of the community's blood pressure distribution. Full phenotypic information was obtained for each individual. DNA was extracted from 5-10 ml of whole blood taken from each individual 15 20 using the standard "salting-out" method (Gentra Systems).

Primer Design

For each SNP, primary PCR amplification primers were designed as described previously⁹. The SBE primer was designed in a manner that its 3' terminates one base before the polymorphic site. Primer 3.0 software package 25 (http://www-genome.wi.mit.edu/cgi-bin/primer/primer3.cgi) was modified and used to pick SBE primers with batch sequences, at a predicted length of 20 (ranging from 18 to 26) nucleotide and melting temperature of 60°C (ranging from 54°C to 64°C). The SBE

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primers were always picked from the forward direction first (i.e. 5' to the polymorphic site). If the SBE primer can't be picked from the forward direction, reverse direction is tried.

Multiplexing PCR

5 Specific genomic regions containing the 144 SNPs were amplified with 9 multiplex PCR reactions, each contains 50 ng of human genomic DNA, 0.1 μ M of each primer, 1 mM deoxynucleotide triphosphates (dNTPs), 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 5 mM MgCl₂ and 2 units of AmpliTaq Gold (Perkin Elmer) in a total value of 25 μ l. PCR was performed on a Thermo Cycler (MJ Research), with initial denaturation 10 of the DNA templates and Taq enzyme activation at 96°C for 10 minutes; followed by 40 cycles of denaturation at 94°C for 30 seconds, 57°C for 40 seconds, and 72°C for 1 minute and 30 seconds; and the final extension at 72°C for 10 minutes.

SBE Template Preparation

1 μ l of Exonuclease I (Amersham Life Science, 10 U/ μ l) and 1 μ l of Shrimp 15 Alkaline Phosphatase (Amersham Life Science, 1 U/ μ l) were added to a 25 μ l PCR products (see above), and incubated at 37°C for 1 hour. The enzyme activities were inactivated at 100°C for 15 minutes. The enzymatically treated samples were applied to a S-300 column (Pharmacia), as to further reduce the residual PCR primers and dNTPs, and replace the buffer with ddH₂O.

20 Multiplexing SBE Reaction

SBE is carried out in a 33 μ l reaction, using 6 μ l of the template (see above), 1.5 nM of each SBE primer, 2.5 units of Thermo sequenase (Amersham), 52 mM Tris-HCl (pH 9.5), 6.5 mM MgCl₂, 25 μ M of fluorescein-N6-ddNTPs (NEN), 7.5 μ M biotin-N6-ddUTP or biotin-N6-dCTP, or 3.75 μ M biotin-N6-ddATP, and 10 μ M the 25 other cold ddNTPs.

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Extension reaction was carried out on a Thermo Cycler (MJ Research), with 1 cycle of 96°C for 3 minutes, then 45 cycles of 94°C for 20 seconds and 58°C for 11 seconds.

After SBE reaction, 9 reactions from each sample were combined and mixed 5 with 30 μ l of 100 μ g/ml glycogen (Boehringer Mannheim), 18.75 μ l of 8 M LiCl (Sigma), and 1125 μ l of pre-chilled (-20°C) ethanol (Abs.), and precipitated by centrifugation at the top speed (Eppendorf centrifuge 5415C) for 15 minutes at room temperature; precipitated samples were dried at 40°C for 40 minutes and re-suspended in 33 μ l ddH₂O.

10 Tag Array Design and Hybridization

For each tag sequence, two probes were synthesized on the array. One is exactly the designed tag sequence (referred to as a Perfect Match, or PM probe). The other one is identical except for a single base difference in a central position (referred to as a Mismatch, or MM probe). The mismatch probe serves as an internal control for 15 hybridization specificity. Over 32,000 20-mer tag probes (and their companions) were chosen¹¹ and fabricated on a 8 mm x 8mm size of array. Each probe (feature) occupies a 30 microns x 30 microns area. The sets of arrays were synthesized together on a single glass wafer on which 100 arrays were made.

The labeled sample was denatured at 95°C - 100°C for 10 minutes and snap 20 cooled on ice for 2 - 5 minutes. The tag array was pre-hybridized with 6 X SSPE-T (0.9 M NaCl, 60 mM NaH₂PO₄, 6 mM EDTA (pH 7.4), 0.005% Triton X-100) + 0.5 mg/ml of BSA for a few minutes, then hybridized with 120 μ l hybridization solution (as shown below) at 42°C for 2 hours on a rotisserie, at \approx 40 RPM. Hybridization Solution consists of 3M TMACL (Tetramethylammonium Chloride), 50 mM MES 25 ((2-[N-Morpholino]ethanesulfonic acid) Sodium Salt) (pH 6.7), 0.01% of Triton X-100, 0.1 mg/ml of Herring Sperm DNA, 50 pM of fluorescein-labeled control oligo, 0.5 mg/ml of BSA (Sigma) and 29.4 μ l labeled SBE products (see below) in a total of 120 μ l reaction.

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The chips were rinsed twice with 1X SSPE-T for about 10 seconds at room temperature, then washed with 1X SSPE-T for 15 - 20 minutes at 40°C on a rotisserie, at \approx 40 RPM. And then wash the chip 10 times with 6X SSPE-T at 22°C on a fluidic station (FS400, Affymetrix). The chips were stained at room temperature with 120 μ l staining solution (2.2 μ g/ml streptavidin R-phycoerythrin (Molecular Probes), and 0.5 mg/ml acetylated BSA, in 6 x SSPET) on a rotisserie for 15 minutes, at \approx 40 RPM. After staining, the probe array was washed 10 times again with 6 x SSPET on the FS400 at 22°C. The chips were scanned on a confocal scanner (Affymetrix) with a resolution of 60-70 pixels per feature, and two filters (530-nm and 560-nm, respectively). GeneChip Software (Affymetrix) is used to convert the image files into digitized files for further data analysis.

Clustering Analysis

For a given marker (at a given tag probe position), the intensity of each of the two colors (fluorescein and phycoerythrin) was calculated as the intensity at the perfect match position (PM) minus that at the mis-match position (MM). Negative fluorescein or phycoerythrin intensity values are treated as if they were zero. The Phat values were computed as the ratio of the intensities (fluorescein/fluorescein + phycoerythrin). The Phat values were sorted, and the optimal set of ranges for AA, AB and BB genotypes given the hypothesis of 2 or 3 clusters was considered, subject to the following rules: at most 4 points (outliers) may be excluded from the genotype ranges. For 2 groups, the total range Phat values must be at least 0.3. For 3 groups, the total range Phat values must be at least 0.5. Ranges must be separated by a gap of at least 0.1. The width of a range may be at most 0.4. A score was then computed as: Score = 1 - (sum of range widths / total range) - (outliers * 0.1).

The set of ranges with the best score was found and used to call genotypes. This score increases with narrow ranges, while decreases with the number of points that are left out of any range. Therefore, it tends to be optimal when all the phat values are contained within relatively small ranges.

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ABI Sequencing to Determine Genotypes

To independently confirm the genotypes called from the tag array assay, three samples (904957000000, 904896000000, and 904889000000) were sequenced using gel-electrophoresis based method. Samples were amplified for all sites with T7 and T3 5 tagged primers, using standard PCR cycling conditions (2.5 μ l of 20 ng/ μ l DNA, 0.375 μ l of 20 μ M primer (X2), 1.5 μ l of 10X PCR buffer, 0.9 μ l 25mM Mg²⁺, 0.15 μ l 10mM dNTPs, 0.25 μ l 10 U/ μ l Taq DNA Polymerase (Sigma), brought up to 15 μ l with ddH₂O per tube). Some products were sequenced directly, while a M13 nesting strategy was used due to the close proximity of the polymorphic base to the primer end. 10 Samples from the initial amplification were diluted 1:50 with ddH₂O, and amplified with M13F-T7 (TGTAAAACGACGCCAGTTAATACGACTCACTATAGGGAGA; SEQ ID NO: 9) and M13R-T3 (AACAGCTATGACCATGAATTAACCCTCACTAAAGGGAGA; SEQ ID NO: 10) primers using standard PCR conditions. All PCR products were cleaned with 15 Exonuclease I (Amersham 0.15 μ l of 10 U/ μ l per well) and Shrimp Alkaline Phosphatase (Amersham, 0.30 μ l of 1 U/ μ l per well) in a volume of 10 μ l. Dye terminator sequencing using a M13R primer (AACAGCTATGACCATG; SEQ ID NO: 11) or T7 primer (TAATACGACTCACTATAGGGAGA; SEQ ID NO: 12) on an 20 ABI377 (Perkin Elmer) using Big Dyes (Perkin Elmer) was performed to determine the genotype status for each SNP in all three individuals. Trace files were read with Edit View 1.0 (Perkin Elmer) software.

EXAMPLE 1

DNA from a individual is isolated, and amplified with primers from 15 previously-characterized (i.e., known) SNPs. Amplification is allowed to proceed as 25 described in Hudson, T.J. *et al.* (Science 270:1945-1954 (1995)) and Dietrich *et al.* (Dietrich, W. F. *et al.*, Nature 380:149-152 (1996); Dietrich, W. F. *et al.*, Nature Genetics 7:220-245; Dietrich, W. *et al.*, Genetics 131:423-447 (1992)). For example, in a 50 μ l reaction volume, 0.5 ng of template nucleic acid/target polynucleotide is added

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to 1 μ M forward amplification primer, 1 μ M reverse amplification primer, 200 μ M dGTP, 200 μ M dTTP, 200 μ M dATP, 3.5 mM MgCl₂, 1.0 mM Tris-HCl (pH 8.3), 50 mM KCl, 0.02 μ M molecular probe, and 0.25 units of polymerase enzyme. The reaction mixture can then be subjected to a two-step amplification process, performed

5 on a Tetrad (MJ Research, Watertown, Massachusetts), with the conditions: denaturation at 94°C for 60 seconds, followed by an annealing/extension step at 53°-56°C for one minute. The denaturation and annealing/extension steps are repeated for 40 cycles. Alternatively, a three-step thermocycling reaction can be used, such as 94°C for 60 seconds, followed by annealing at 53°-56°C for 30 seconds, followed by
10 extension at 72°C for one minute the three steps being repeated for 40 cycles. This may be followed by an optional extension step at 72°C for five minutes.

After amplification is complete, locus-specific tagged oligonucleotides specific for the 10 SNPs are added, and are allowed to hybridize to the amplification products.

15 Reagents for a single base extension reaction are then added, where each of the four ddNTPs is labeled with a different fluorophore. Single base extension is then performed as described by Kobayashi et al. (Mol. Cell. Probes 9:175-182 (1995)).

20 After the reaction is complete, the reaction products are placed in contact with the universal array, and the reaction products allowed to hybridize, each product to its appropriate oligonucleotide tag on the array. The chip is then assayed in a fluorometer, and the wavelength emitted at each address in the array is recorded. From this data, the genotype at each individual SNP is determined.

EXAMPLE 2

Two alleles of template were mixed at ratios of 1:30, 1:10, 1:3, 1:1, 3:1, 10:1, and 30:1. These were labeled with different color labels by single-base extension
25 reaction and hybridized to a tag array. A correlation was observed between the signal intensity ratio and the template concentration ratio over a 900-fold dynamic range. See Figure 2.

EXAMPLE 3

A set of tag sequences is selected such that the tags are likely to have similar hybridization characteristics and minimal cross-hybridization to other tag sequences. An oligonucleotide array of all of the tags is fabricated. The design and use of such a 5 4,000-20mer-tag array for the functional analysis of the yeast genome has been described (1). More recently, Affymetrix designed and fabricated an array with a set of more than 16,000 such tags. The tag sequence synthesized on the chip can be 20-mer, 25-mer, or other lengths.

EXAMPLE 4

10 Marker specific primers are used to amplify each genetic marker (e.g. SNP). A multiplex PCR strategy is used to amplify these markers from genomic DNAs of tested individuals (2). After PCR amplification, excess primers and dNTPs are removed enzymatically. These enzymatically treated PCR products then serve as templates in the next SBE reaction. Please note that these templates (PCR products) are double 15 stranded, which are different from the templates used in other protocols (3, 4). For example, in Minisequencing (3) and Genetic Bit Analysis (GBA, 4), a double stranded template has to be converted to a single stranded template prior to the base extension reaction. The methods used for this conversion are costly, laborious, and hard to automate.

20 EXAMPLE 5

In the protocol described below, an SBE primer is designed for each genetic marker which terminates 1 base before the polymorphic site. However, other primer design schemes can be used. The primer for each marker is tailed with an unique tag which is complementary to a specific probe sequence synthesized on the tag chip. The 25 extension reaction is multiplex, in which SBE primers corresponding to multiple markers were added in a single reaction tube, and extended in the presence of pairs of

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ddNTPs labeled with different fluorophores, *e.g.* for an A/C variant, there might be a ddATP-red and DDCTP-green.

EXAMPLE 6

The resulting mixture is hybridized to the tag array. Each tag corresponds to a 5 single marker. The ratio of the intensities of the colors indicates the genotype (or the allele frequency, ranging from 0% to 100%) of the samples tested.

EXAMPLE 7

SBE template preparation: Marker specific primers are used to amplify each 10 single nucleotide polymorphism (SNP). A multiplex PCR strategy is used to amplify these SNPs (Science 280:1077-1082, 1998).

Multiplex PCR:

Multiplex PCR reaction is carried out with AmpliTaq Gold and 25 primer pairs in a 25 μ l reaction volume. SNPs with same base composition at the polymorphic site (i.e. A/G, T/C, etc) are pooled together.

15 **PCR reagents:**

10XPCR Multiplex Buffer (II): 100 mM Tris/HCl (pH 8.3)
 500 mM KCl

25 mM dNTPs

20 F & R Primers (for each primer, the conc. is 1 μ M)
20 ng/ μ l Genomic DNA

Multiplex PCR reaction (25 μ l)

Primer Mix (1 μ M each) 2.5 μ l
Genomic DNA (20 ng/ μ l) 2.5 μ l

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10XPCR Buffer II	2.5 μ l
25 mM MgCl ₂	5 μ l
25 mM dNTPs	1 μ l
AmpliTaq Gold (5U/ μ l)	0.4 μ l
5 ddH ₂ O	up to 25 μ l

PCR conditions

96°C 10 min

40 cycles :

10	94°C	30 sec
	57°C	40 sec
	72°C	1 min 30 sec
	72°C	10 min
	4°C	O/N

Enzymatic treatment of PCR products to degrade and de-phosphorylate the unused

15 primers and dNTPs, respectively:

To a 25 μ l PCR products, add 1 μ l of Exonuclease I (Amersham Life Science, 10 U/ μ l) and 1 μ l of Shrimp Alkaline Phosphatase (Amersham Life Science, 1 U/ μ l), and incubate at 37° C for 1 hour. Inactivate the enzyme activities at 100°C for 15 minutes. Apply the sample to a S-300 column (Pharmacia), to further reduce the 20 residual PCR primers and dNTPs, and replace the buffer with ddH₂O. The sample is ready for next SBE reaction.

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Single Base Extension (SBE):

An SBE primer is designed for each SNP which terminates 1 base before the polymorphic site. The primer for each SNP is tailed with a unique tag which is complementary to a specific probe sequence on the tag chip. The SBE reaction is also 5 multiplexed at 25-plex.

Reaction Mixture (33 μ l):

Template (see above)	6 μ l
SBE Primer mix (20 nM for each primer)	2.5 μ l
5X Thermo Sequenase buffer	6.6 μ l
10 Bio-(d)dNTP(X nmol/ μ l*, NEN)	0.5 μ l
Flu-ddNTP(1nmol/ μ l, NEN)	0.8 μ l
Other two cold -ddNTPs(1nmol/ μ l, Biopharmacia)	0.3 μ l each
Thermo Sequenase(6.4 U/ μ l) (Amersham)	0.4 μ l
15 ddH ₂ O	up to 33 μ l

* X= 0.5 when it is Bio-ddUTP or bio-dCTP(0.5 mM), or X= 0.25 when it is bio-ddATP (0.25 mM)

PCR program:

96°C 3' 1 cycle
20 94°C 25"
58°C 11" 45 cycles
4°C forever

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Precipitation:

After SBE reaction, we combined 9 tubes for each sample, mix with 30 μ l of 100 μ g/ml glycogen (Boehringer Mannheim), then precipitated with 18.75 μ l of 8 M LiCl, and 1125 μ l of pre-chilled (-20°C) ethanol (Abs.). Mix well; then centrifuge at the 5 top speed (Eppendorf centrifuge 5415C) for 15 min at room temperature; Decant the supernatant, and dry the samples at 40C for 40 min, re-suspend the samples in 33 μ l ddH₂O, now it is ready for hybridization.

Hybridization:

The prepared sample is denatured at 100°C for 10 minutes and snap cooled on 10 ice for 2-5 minutes. The universal tag chip is pre-hybridized with 6 X SSPE-T (0.9 M NaCl, 60 mM NaH₂PO₄, 6 mM EDTA (pH 7.4), 0.005% Triton X-100) + 0.5mg/ml of BSA, then hybridized with 120 μ l hybridization solution (as shown below) at 42°C 2 hours on a rotisserie, at \approx 40 RPM.

The hybridization solution contains:

15	5M TMACl	72 μ l
	0.5M MES (pH 6.7)	12 μ l
	1% Triton X-100	1.2 μ l
	HS DNA (10mg/ml)	1.2 μ l
	Flu-c213 (5 nM)	1.2 μ l
20	BSA (20 mg/ml)	3.0 μ l

Plus 29.4 μ l prepared sample (see above).

Post-Hybridization Wash:

Rinse the chip with 1X SSPE-T 10" twice first, then wash with 1X SSPE-T for 25 15-20min at 40°C on a rotisserie, at \approx 40 RPM. And then wash on a fluidic station (FS400, Affymetrix) 10 times with 6 x SSPET at 22°C.

Staining:

Stain the chip at room temperature with 120 μ l staining solution (2.2 μ g/ml streptavidin R-phycoerythrin (Molecular Probes), and 0.5 mg/ml acetylated BSA, in 6 x SSPE-T) on a rotisserie for 15 minutes, at \approx 40 RPM. After staining, the probe array was 5 washed 10 times again with 6 x SSPE-T on the FS400 at 22°C.

Scanning:

The chips were scanned on a confocal scanner (Affymetrix) with a resolution of 60-70 pixels per feature, and two filters (530-nm and 560-nm, respectively). GeneChip Software (Affymetrix) is used to convert the image files into digitized files for further

10 data analysis.

EXAMPLE 7**Genotyping With High-Density Oligonucleotide "Tag" Arrays**

A genotyping method based on the use of a high-density "tag" array that contains over 32,000 pre-selected 20-mer oligonucleotide probes, combined with 15 marker-specific PCR amplifications and single base extension (SBE)¹⁻² reactions has been developed. We have used this method to genotype a collection of 144 single-nucleotide polymorphism (SNPs) identified from 49 hypertension candidate genes³. First, marker-specific primers were used in multiplex PCR reactions to amplify specific genomic regions containing the SNPs. The PCR amplified DNA products were 20 then used as templates in SBE reactions. Each SBE primer comprises a 3' portion and a 5' portion. The 3' portion is complementary to the specific SNP locus and terminates one base before the polymorphic site. The 5' portion comprises a unique sequence, which is complementary to a specific oligonucleotide probe synthesized on the "tag" array. The extension reaction is multiplex, with SBE primers corresponding to multiple 25 SNPs in a single reaction tube. The primers are extended in the presence of two-color labeled ddNTPs, and the resulting mixture is hybridized to the tag array. The intensity ratio of the two colors was used to deduce the genotypes of the samples tested.

The tag array strategy begins with an array of tag sequences selected in a manner that all tag probes are in the same length, *e.g.* 20-nucleotide long, with similar melting temperature and G-C content, and the lowest sequence homologous among each other¹¹. Therefore, these tags are likely to have similar hybridization characteristics and minimal 5 cross-hybridization to other tag sequences.

The design and use of a 4,000-tag array for the functional analysis of yeast *Saccharomyces cerevisiae* genes¹¹ and drug sensitivity studies¹² have been described. More recently, we have designed and fabricated an array that contains more than 32,000 such tags, and developed it as a genotyping tool, in combination with marker-specific 10 PCR amplifications and SBE reactions.

As shown in Fig. 7, marker specific primers are designed and used to amplify each single nucleotide polymorphism (SNP). A multiplex PCR strategy is used to amplify these SNPs from genomic DNAs⁹. In general, SNPs with same base composition at the polymorphic site (*e.g.* all the A/G polymorphisms) are grouped 15 together. After PCR amplification, excess primers and dNTPs are degraded and de-phosphorylated using Exonuclease I and Shrimp Alkaline Phosphatase, respectively. These enzymatically treated PCR products (double-stranded) are then served as templates in the SBE reaction. A SBE primer is designed for each genetic marker, which terminates one base before the polymorphic site. Each primer is tailed with a 20 unique tag that is complementary to a specific probe sequence synthesized on the tag array. The extension reaction is multiplex, in which SBE primers corresponding to multiple markers (up to 56 markers that we have tested so far) were added in a single reaction tube, and extended in the presence of pairs of ddNTPs labeled with different fluorophores, *e.g.* for an A/G variant, biotin-labeled ddATP and fluorescein-labeled 25 ddGTP are used. The resulting mixture of SBE reactions is hybridized to the tag array. Each tag hybridizes to a specific probe position on the chip. The ratio of the intensities of the colors indicates the genotype (homozygous wild type, or homozygous mutant, or heterozygous) or the allele frequency (ranging from 0% to 100%) in the samples tested.

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In a comparison of the results of using single-stranded and double-stranded PCR products as the templates in the current SBE/tag array assay, no significant difference was found (data not shown). However, in previously published protocols of minisequencing¹³⁻¹⁵ and genetic bit analysis¹⁶⁻¹⁸, a double-stranded template has to be converted to a single-stranded template prior to the base extension reaction. The methods used for this conversion were costly, laborious, and hard to automate.

The tag array assay provides a fairly accurate quantitative measurement of the allele frequency in samples tested. As shown in Figure 2, we have synthesized two artificial SBE templates. They are identical, except the 21st position: T in template-T, and G in template-G. We then mixed the two templates at ratios of 1:10, 1:3, 1:1, 3:1, 10:1, and 30:1, which is a 300-fold dynamic range. Six SBE primers, which have the same 3' portion (the portion complementing to the template sequence) but different 5' portion (the portion complementing to the tag probes on the tag arrays) were designed (Figure 2), and extended in the presence of the SBE templates mixed at different ratios, and biotin-labeled ddATP and fluorescein-labeled ddCTP. As shown in Fig. 8, the intensity ratio of the two colors and the template concentration ratio (i.e. the allele frequency) appears to form a fairly good linear correlation in the 300-fold dynamic range that we tested.

To further test the robustness and the efficiency of the tag array/SBE assay method for genotyping application, we set out to type a portion of the SNPs that we had identified from a large-scale polymorphism screening study with the hypertension candidate genes³. Initially, we selected 173 SNPs from 56 hypertension candidate genes. These SNPs were chosen for their being occurred in promoter regions, or splicing junctions, or coding regions in which the nucleotide changes caused amino acid changes. We reason that these SNPs can be the good candidates for being the functional mutations predisposed to the disease. Therefore, the assay developed in this study could then be used in large-scale association studies in hypertension. PCR primers were designed and tested individually for these 173 SNPs. 8 of them (4.6%) failed to amplify. SBE primers were then designed for the remaining 165 SNPs. A multiplexing PCR and

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multiplexing SBE assay was developed with a complexity of 9 to 28 markers in each reaction and a total of 9 reactions for the 165 markers. 21 of them (12.7%) failed in the multiplexing PCR and multiplexing SBE assay. Therefore, 144 markers from 49 genes passed the assay development. The gene location, polymorphic sites, and the designed 5 primers for these 144 markers were summarized in Table 1.

We then genotyped 44 individuals using 44 tag arrays. Good hybridization signals were obtained in 96.5% (6116 / 6336 (144 x 44)) of the cases. The signal intensity values from the hybridization results were used in clustering analysis for each of the 144 markers. Genotypes for each individual at the 144 loci were assigned 10 automatically based on the clustering results, with some manual editing. Data Desk 6.0 (Data description, Inc.) was used to manually display the clustering analysis results (of the intensity ratios of the two colors). Overall, 80-85% of the markers form good cluster(s).

We have performed the gel-based DNA sequencing to determine the genotypes 15 at 115 loci in 3 of the 44 individuals (see Methods). Comparison of the ABI sequencing results and the chip results resulted in 14 discrepancies (4%), out of 115 x 3 = 345 genotype calls. Most of the discrepancies occurred in cases where one method called homozygous, while the other method called heterozygous. In one case (marker ICAM1ex6.254), where the ABI sequencing method called G/G, but the tag array /SBE 20 assay method called A/A in all the three individuals, we believe the discrepancies are due to mis-priming of the SBE primer to adjacent sequences.

We also tested the reproducibility of the tag array/SBE assay genotyping 25 method. We repeated the multiplexing PCR, SBE and the chip hybridization experiments in 4 individuals. The ratios of the two colors (for each of the 144 markers) in the replicated experiments are not all exactly the same, but they all fall into the same cluster (i.e. giving the same genotype call). Therefore, we didn't find any discrepancy in the genotyping call of duplicated samples.

TABLE 1

Gene/Exon/Position	SNP Flanking Sequence	Forward Primer	Reverse Primer	SBE Primer
AADDEX10.246	TTCCGAGGAA(G/T)GGCGAGAATGG	GACCGAAGCTTCCGAGGA	GGGACTGCTTCCATTTCGTC	AGAGTCTATAAGCAT CGTCGGGGCAGCGAAG CTTCCGAGGAA
AADDEX13.173	CAGAAGGGCT(C/G)TGAAGGTGAG	GAGAGGAAGCAGAAGGGC	GACCCACAAGCCTCACCTTC	TGAGACAATTCTATA CGCGGTGGAGAGGGAA GCAGAAAGGGCT
ACEEX13.138	TGCTGGTCCC(C/T)AGCCAGGAGG	GCACCCCTGCTGGTCC	TGACTGTACCTGTGGGA	TCGTGAGTTGTCCTGC TGCAGCACCCCTCTGC TGGTCCC
ACEEX13.151	CCAGGAGGA(T/C)CCCAACAGGT	GCACCCCTGCTGGTCC	TGACTGTACCTGTGGGA	GCCTGTAAATGGTGGAA TCTCAGTCCCCAGCC AGGAGGCA
ACEEX13.202	AACAAACCAGC(A/G)GCCAGACAAC	AGCCAGGAAACAACCAAG	GTGGGGGGTTGTCCTGCC	GATCTGTCTGACGCT GTATGGCAGCCAGGC ACAACCCAGC
ACEEX15.144	AACGGGCAGG(G/A)CTGCCCTGCC	AGGACCTAGAACGGCAG	TCCTGGGCAAGGCAGC	CGTGATAATGGTCT CGTAGGAGGACCTAG AACGGGAGC
ACEEX17.19	AGCCATTCAA(C/A)CCCCTACCAAG	TGGAGCTCAAGGCCATTCA	CGTCAGATCTGGTAGGGGG	CATTATCGGACATGC TCACCTGGAGCTCAA GCCATTCAA
ACEEX17.52	TGATGGCCAC(A/G)TCCCCGAAAT	GACGAATGTGATGGCCA	GGTCTTCATATTTCGGGAT	ATGATGAGCCGTGAT GACCCCTGACGAATG TGATGGCCAC
ACEEX18.130	CACTCTACCT(C/G)AACCTGCATG	GAGCTGAGCCACTCTACC	CGTAGGGCATGGCAGGTTG	TACATCGCTTGCATG AGTGTGAGCTGCAGC CACTCTACCT

ACEEX21.150	CATGAGGCCA(T/C)TGGGGACGTG	CGGCTTCATGAGGCC	GGCTAGCACGTCCCCCAA	GATCTGGCTTCAACT GTATGCCGGCTTCCA TGAGGCCA
ACEEX22.19	TGACATCAAC(T/G)TCTGATGAA	TGGCAGAGCATGACATCAA	AAGGGCCATCTTCATCAGA	TGCCTAGCTTCCATA TGGCCTCTGAGAGC ATGACATCAA
ACEEX24.118	CCAAGGAGGC(C/T)GGGAGGCC	CATCTACAGTCCAAGGAG G	TCACCCAGGGCTGC	TATCTCGC1TGCTATC AACGATCTACAGTC CAAGGAGGC
ACEEX24.16	CCAGGTACTT(T/C)GTCAGGCTCA	TCGGCTCTGCTCCAGGTA CT	GGAACTGGATGTATGAAGCT GA	GCCTAAAGCTCTGTC CTGATTTCGCTCTGCTC CAGGTACTT
ACEEX26.154	CTCAGCCAGC(G/A)GCTCTTCAGC	CTGGGCCCTCAGGCCAG	GCGGATGCTGAAGAGCC	TCTATTGCTGTTGGC GGCAACCCCTGGCCT CAGCCAGC
ACEEX26.174	CATCCGCCAC(C/A)GCAGGCTCCA	TCTTCAGCATCCGCCA	GCGGGTGGAGGCTGC	AGCAGAGATGGACAG ACCTCTCTCAGCAT CCGCCAC
ACEEX26.205	CACGGCCCC(A/C)GTTGGCTCC	CACTCCCACGGGCC	CACCTCGGAGGCCAACT	GCTGGGGGTTCATGC AACTCTCCACCTCGG AGCCGAAC
ACEEX26.224	CCGAGGGGA(G/A)CTGAGACAT	TCGGCTCGAGGTGG	CACCTCAGGAGTGTCTCAGC	TATCTCGGTTGCTGAC GTGCCAGTTCGGCTC CGAGGTGGAA
ACEEX8.106	AGGATCTGCC(C/T)GTCTCCCTGC	CCTGCAGTACAAGGATCTG C	CCGACGCCAGGGAGA	GATCCGTTATGTCGAA TGGCTCTGAGTACA AGGATCTGCC
ACEP-3892	TAAGGGGGG(T/C)TGCTGTACAT	CCACTGAGGATAAGGGGG	GAAGATAATTGCAAAGTAT GTACAGC	CCAGAGGTGGTCA CATATCACTGAGGAT AAGGGGGG

ACEP.-5466	TATAGTATA(T/A/C)ATGCCAGC	GTCATGCCATGTCAACATATA TTATAGT	GACCATGGCTGGGCAAT	GCATCTTICGCCAGCT ATATTGGTTGACCAT GGCTGGGCATA
ACEP.-93	GCTGGGGACT(T/C)TGGAGGGAG	AGGAACCTCGGGCCG	GCTTCCTCCTCCGCTCC	CACTTACGGCCATGCTGC TGAATCCCGCCGC TGGGACT
ADD BEX1.85	AGTCTTCAG(C/T)GTTGCCCTCC	CCGTGTGCGAGTTCTCTCA	CCAGATGGAGGGCAA	CACTGTACCGCACTGG AGCTACGTGTCGAG TCTTCAG
ADD BEX3.138	CTCAGAGGAC(G/A)ACCCCGAGTA	TGACCGCTTCTCAGAGGA	GCGCATGTACTCGGGG	GTTGCAATTGAGTCT ATGACTTGTGACCGCTT CTCAGAGGAC
ADRB3EX1.416	GGCCATCGCC(T/C)GGACTCCGAG	CATCGTGGCCATCGC	CTGGAGTCTCGGAGTCCA	CGTCTCATGCTCGGT ATAGTGGTCAATCGTG GCCATCGGCC
ADROMEX3.81	GGATGTCCAG(C/G)AGCTACCCCA	GGAACTGGGATGTCCA	GCCCCGGGGTAGC	TACATCATTTGCGAGT CATGGAAGGGAAAC TGCGGATGTCCAG
AEIEX14.159	CTTCTTGGC(Q/A)TGTGTCGCG	CCGGTACCTCTCTTGC	TGAACCTGCGCAGCATC	ATACGCTCTGCCATA CGTGAGCGGGTACCT TCTTCTTGGC
AEIEX4.36	TCA GCTCAC(A/C)ACCGAGGCA	CCGACCTCTGGTTTCAGC	TGGCTGTTGGCTCGGT	TTGGCCAATTGGAC ATGCTACCTCTGGTT TCAGCTCAAG
AEIEX4.89	GGGTACCCAC(A/G)AGGTGAGGAC	CACACCGGGTACCCA	GGCTGGGCTCTCAC	GCCTGATATTCTATTCA CAGCACATCACACCC GGGTACCCAC
AGT.385	CCGTTCTCC(T/C)TGGTCTAAGT	GACCTTGAGCTGGAAAGCA G	CATGGCAGCACCTAGACC A	CTGTCGTTAGTCTCT GAGGCATGAGGACACA CTTAGACCA

AGTEX2.354	GGATGCTGGC(C/T)AACTTCTTGG	TGGTCGGATGGCTGG	CGGAAGCCCAAGAACGTTG	TTCGGTGCCTTGGAG ACAGCAATGGTGGG ATGCTGGC
AGTEX2.755	TTCACAGAAC(T/G)GGATGGTGGCT	CGCTCTCTGGACTTCACAGA	TCTCAGGAGCAACATCCA	TGCCGTGTTGGACTT CACACTCTGGACTT CACAGAAC
AGTEX2.827	TGCTCCCTGA(T/C)GGGAGGCCAGT	AGACTGGCTGCTCCCTG	TCCACACATGGCTCCCA	TGTCACACTTGGCAT GATGAAGAGCTGGCTG CTCCCTGA
AGTEX5.376	GGAAAGCAGC(C/G)GTTTCTCCCT	GAAGTTGAGCTGGAAAGCA G	CATGCAGCACACTTAGACC A	TACATACGGCAGTGC CGTTCACCTTGAGCTG GAAAGCAGC
AGTEX5.385	CCGTTTCTCC(T/C)GGCTAACT	GACTTGAGCTGGAAAGCA G	CATGCAGCACACTTAGACC A	CGTCGTGCTGGCTGA CTATAGGAAAGCAGC CGTTTCTCC
AGTEX5.641	TCGGTTTGTAA(T/G)TTAGTGTCTT	GCATTGCTTCGGTTGT	TCATGTTCTTACATTCAAAGA CACTAAA	TGAGAGTCGTGTCIT AGGCCATTTGCAAT TGCTTCTGGTTGTA
AGTEXP1.101	CTGTGCTATT(G/C)TTGGTGTAA	CTTTCAAATCTGGCTGTGCTA T	GGGGAGACTGTAAACACC AA	TACATAATTGCCATG ACGGGTTCAATCTGG CTGTGCTATT
AGTEXP2.160	CCTTGGCCCC(G/A)ACTCTGCAA	TGGGAACCTGGCCCC	ACCGAAGTTGCAAGGAGTC	GAGAAATGCTGTATAG TGTCTTTCTGGGAAC CTTGGCCCC
AGTEXP2.203	ACCCCTGCAAC(G/A)GCTCACTCTG	TGTGTAACCTGACCCCTGAC	CTGCTGAACAGAGTGTAGGCC	CGTCTCGCTGGTCACT AATGGCTGTAACTCGA CCCTGCACC
AGTEXP2.35	CTGCAACCTCC(G/A)GCCCTGCATGT	TCTGCCCTCTGCACCTC	CAGGGACATGCAGGCC	GAATCTCTGTGAAGTT AGTGGCCCTCTGCCCT TGCACCTCC

AGTEXP3.144	TAAAATAGGGC(C/A)TCGTGACCCG	CACCCCTCAGCTATAAATAG GG	CGGCAGGCTCTTCCCC	TATAAAGATTGGGGT CAGGCCCTCAGCTA TAAATAGGGC
AGTEXP3.158	TGACCCGGCC(A/G)GGGGAAAGAAG	CACCCCTCAGCTATAAATAG GG	CGGCAGGCTCTTCCCC	CCAGTCGGGTAGCA GCAATTAGGGCCCTG TGACCCGGCC
AGTEXP3.173	AAGAAAGCTGC(C/T)GTTGTTCTGG	GCCAGGGGAAGAACGCTG	GCTGTAGTACCCAGAACAA CG	GTGTGCTCTCTCGCT GCAAGCCAGGGAAAG AAGCTGC
ALDREDEX1.162	CAAGATGCC(A/T)TCCTGGGTT	ACGGCGCCAAGATGTC	AGGTACCCAAACCCAGG	ATACCGGGCTGCTACA CAGTGAACGGGGCCA AGATGCC
ALDREDEX1.71	GTACGGCCG(C/G)GGCCAAGGCC	GCTATTAAAGGTACGGCC	TACGGTGGGGCTTIG	CAAATAGTGTGCGAG GATCTGCTATTTAAA GGTACGGCGCCG
ALDREDEX3.28	TCGCTGGCT(A/T)GCTGTAGTGC	GCCCTCTCGCTGGCT	CATGGTACGTGACACAG	TGAGACATTTGCAA ATCGGACATGTGCCC TCTCGCTGGCTT
ANPEX3.33	TTTGCAAGTAC(T/C)GAAGATAACA	ATATGTCGTTGTTCTTTG CAGT	CTCCCTGGCTGTTATCTTCA	GATAGCAGGTCACTA CCTGGGTCTGTGTTCT CTTGCAGTAC
APOA2.249	TCCTGTTGCA(T/C)CAAGTCAA	TTGGAATCTCTGTTCTGT	GATCTGAGGTCCTTGACTT G	GGCATCACTGGTTAC GTCTGATCTGAGGTC CTTGGACTTGA
APOA4.3058	AGGAAACAGCA(T/G)CAGGAGCAGC	AGCAACAGCAGGAACAGC	CACCTGCTCTGCTAC	GTCTGACTTGAGTTA CATGGGAGCAACAGC AGGAACAGCA
APOCIEX1.462	TTCCTGTCGAT(C/G)GTCTTGGAAAG	TGGGGTTGGTTCTGTCGA A	TCCCACTTTACCTTCAAG A	GCTCTTCCTATATGTG CGGGTCTCTGGTTGGTG GTTCCTGTCGAT

APOC2.804	CTTCTCCCC(A/T)GGGACTTGTAA	ACCATCTGTGCTTCCTCCC	TCATGGCTGTGCTT	TGAGAAGTTGTGAAG ATCCCTAACCATCTGT GCTTCTCCCC
APOC2.819	CTTGACAGC(A/C)AAAGCACAGC	ACCATCTGTGCTTCCTCCC	TCATGGCTGTGCTT	GCCAGGGCTTCAGAT GCAAATCCAGGGACT TGTACAGC
APOC4.3162	CTGGTCCGG(T/G)ACCAAGGCC	AGGGACCTGGGTCCG	AGGAACCAGGGCTTGGT	GCTGGTCGGTCCA ATCA TTGAGGGACCT GGTCCGC
APOER2EX12.68	ACTGTCCAGC(A/C)TTGACTTCAG	CAAGCTACACCAACTGTCC AG	TCTGTTGGCTCCACTGAAG	GACCATGCTGGCTTA CCTGTAAGCTACACC AACTGTCCAGC

AT2EX3.807	GGGAAGAACAG(A/G)ATAACCCGT	GACGAATAGCTATGGGAAG AAC	ACTTGGTCACGGGTTATCC	TGGCATCGTTTCACCT GCTGGACGAATAGCT ATGGGAAGAACAA
AVPEX2.154	AACTACCTGC(C/T)GTCGCCCTGC T	TGCCAGGAGGAGAACTTACCC	GGACTGGCAGGGCGA	TATCATTCCTGGTGTGCG CGGCCAGGAGGAGA ACTACCTGC
AVPR2EX2.129	GCGGAGCTGG(C/T)GCTGCTCC	CTAGCCCCGGGGAG	CCACAAAGACTATGGAGAG CAG	GTGGATCTTGATGTA ATGGCTTAGCCCCGGGC GGAGCTGG
AVPR2EX2.444	CCCATGCTGG(C/T)GTACGCCAT	TGCCGTCCCATGCTG	CCACTTCCATGGGGTA	GCCGTCAATGGGTGC TCAATATCTGCCGTCC CATGCTGG
BIR.1521	GGCACTTGA(C/T)GGTGTGCCA	AGTGGTGTGGCACCTTG	CTACTCCAAGTTGGAAACA C	GCCAGTCAATCCACG TATAATAGTGTGGTGT GGGCACTTGA
BIR.2463	TACCTGGCT(T/C)GGCAGGGTCC	GGCACGGTACCTGGGC	CGCCTGGAGGGAC	CCAGGCCATGTGTGC AATGAGGGCACGGTA CCTGGGCT
BR33EX1.730	CATCTATTT(A/C)CTTATGCTGT	GAAGCATTTGTGTGCCATCTA	CCACTGAAATGATCACAGC A	ATCTCAGAGTGGCAT CGGATAGAAGCATGG TGTTGCCATCTATATT
CAL/CGRPEx4.30	TTCCCTGCAG(C/A)CTGGACAGCC	CTGGTATGTTTCTGC	CTTAGATCTGGGCTGTCC	GTCCTGCAATTATCGG CTGTGTCTGGTATGT GTTTTCCCTGCAG
CaR.AA1011	GACCCGACACCC(G/A)GCCATTACT	CGATACGGCTGACCCGACA	GCAGGGGAGTAATGGC	GGCTCTGCAATTCTGCTG ATATGAGGCAATACGC TGACCCGACAC
CaR.AA990	CATGGCCAC(G/A)GGAATTCTAC	CTTGATGAGCTCAGAAAG AA	GGAGTTCTGGTGTAGAAT TC	GCGAATTGAAGGCCAG TTGCAAGAAGAACGC CATGGCCAC

CHYEX2.168	ACGGCTGCTCA/GYTTGTGCAAGGA	TGTGCTGACGGCTGCT	TGTCTCACCTTCCCTGCACA	CCATCGAATACGCTTA TCAGTACTTGTGCTG ACGGCTGCTC
CLCNKBEX10.33	GGCCACCTTG(G/C)TTCTCGCCTC	CCGGCTCTGCCACCTT	AGGTGATGGAGGCCAGA	GGTCTCAATTAGGCT TCATGTACTCCGCTCT GGCCACCTTG
CLCNKBEX15.64	GCCAAGGACA(C/T)GCCACTGGAG	CCACACTGGCCAAGGA	CCTTGACCACCTCTCA	GCGGTCATGTGCTC TGATATCACACACACT GGCCAAGGACA
CLCNKBEX4.19	AATCCGGAG(GC)TGAAGACCAT	GGTTCTGGAATCCCGGA	CCGCCAACATGGTCTTC	GCGTGTATATTCCATG ATCTGAGGTCTGGAA
CLCNKBEX4.70	GGATATCAAG(A/C)ACTTGGGC	TGGAGGACTACTGGATAT CAA	CCACTTGGCCCAA	GCTGGTGTGGCTCT TCATATGGAGGACTA CTGGATATCAAG ATCCGGAG
COX2EX1.358	CCAATTGTCA(T/G)ACGACTTGCA	CGGTAGCGACCAATTGTC	GACGCTCACTGCAAGTCG	CGAACATCTGTACA ATGGCTCTGGTTAGC GACCAATTGTCA
COX2EX10.156	ATGGTAGAAG(T/C)TGGGACCA	TTTGGTGAACCATGGTAG AA	TCAAGGAGAAATGGTGCTCC	GAECTTAGTGTGCTCT GATCTCTTGGTGAAG ACCATGGTAGAAG
CYP11B1EX4.205	AGGAGCACTT(T/G)GAGGCTGGG	AAGGTGTTGAAGGAGCACT	ATGCAGTCCCAGGCC	TCAGATGTGTAATC GTGCGCAAGGTGTTG AAGGAGCACTT
CYP11B1EX5.107	CGTGGGGAG(C/G)TCCTGTTGAA	CAGTACACCAGCATCGTGG	AGTTCCGCAATTCAACAGG	GCGTGGCTTCATGC GATATTACACCAGCA TCGTGGCGGAG
CYP11B2EX3.152	CAGGCCCTGA(A/G)GAAGAAGGTG	CGAGTGGCCAGGGACT	CGTTCTGCAAGCACCTCTT	ATGCACGATCCCTCA CATTGGGACTTCTCCC AGGCCCTGA

CYP11B2EX6.91	GTGCAAGCAGA(T/C)CCCTGCCAG	CCCGACGTGCCAG	GCTCTCTGGCCAG	CTTACCCATGATTAG CCGAGGGAAACCCGA CTTGCAGCGAGA
CYP11B2EX7.65	GAGGAGTGG(T/C)GAGCTAGAC	GCTCTACCTCTGTGGCTGT	TGAAGCACCAAGTCTGAGC T	GCGGATGGTGCCT ACTATGTCGTGTTTG GAGCGAGTGG
DBHEX3.153	GCCCTCAGAC(G/A)CGTGCACCAT	CGGAGATGCCCTAGA	GGACCTCCATGGTCAC	TGGCAGGGTTGTGACT CTCTCAACGGAGTT GCCCTCAGAC
DBHEX4.132	GATGAAACCC(G/A)ACCGCCTCAA	GCGACTCCAAGATGAAACC	GGCAGTAGTTGAGGGGG	TATGATTATGAGTG CGGGCCTGGAACCTCC AAGATGAAACCC
DBHEX5.39	AGCGGGCTT(G/T)CCTTCGGGG	CCAGAGGAAGCCGGC	CCTGGACACCCCTCAAG	TGAGATCGTCTTGCTG TGAAACCCAGAGGAA GCCGGCCTT
DD1R.122	CTCAAGGGAC(A/G)ACCCCGAGTA	TGACCCCTATTCCCTGCT	CTCTGACACCCCTCAAGTTC	TTTGAGATTGTCGA GAGGCCACTGACCCCT ATTCCCCCTGCTT
EDNRBEX3.144	GATATAATTAC(T/G)ATGGACTAC	CTGAAGGCATAGGTTTGAT ATAAT	GCAGATAACCTCCCTTGTAG TCCA	GCCTGCTGGGCTGT ATATCAGATAACTTC CTTGTAGTCCATC
ELAM1.77	GAATTCTGQ(C/T)GCTGGACTCT	CCTTGGTAGCTGGACTTCT G	GTCAAGGAGGGAGAGTCCAG	GATCACTGTTGGCTCC TGCTCTGAGCTGGAC TTCTG
ELAM1EX5.197	TTGGGACAAAC(G/A)AGAAGCCAAAC	CATCTGGAAATTGGGACAA	TCTACCTTACACGTTGGCT TC	TATGAGTGTGGCT ATGCCTCATCTGGGA ATTGGGACAAAC
ELAM1EX7.200	GTGGGACAAAC(G/C)AGAAGCCAC	CACAGGGAGTGGGACA	CCTTCACATGTGGGCTTC	GGTICGGCTGTGTTG ACTATCCACAGGGGA GTGGGACAAAC

eNOS.78	CCCCAGATGA(T/G)CCCCAGAAC	TGCAGGCCAGATG	CAGAAGGAAGAGTTCTGGG G	ATACGGGATGATGATGAG CATACTGCTGCAGGC CCAGATGA
ET1EX5.90	TGAAAGGCAA(G/T)CCCTCCAGAG	TCCCCAAGCTGAAAGGCA	CACATAACGCTCTGAGG	TACATGACTGCTGCCT GCTGTTTCTGATCCC AAGCTGAAAGGCAA
GALNREX1.327	GCACGGAGCC(G/C)CTCGGGAGC	CAGGTGCAGCACGCA	TCCCTGGCTCCCGGA	ACGATGAGCAGGGAT CACTAACAGGTGCAG CACGGAGCC
GALNREX1.553	TCAGAAAGGT(G/C)CGGGCGAAAG	CCCACCCCTCTCAGAAAGGT	CACCGTCTTGCGCC	ATCTGAGAGCTAGTC GGCATCCACCCCTCT CAGAAGGGTC
GGREX9.29	AACATGGGT(T/G)CTGGTGGATC	AGCAATGACAACATGGGC	CCGCAGGATCCACCA	GGTGACTATTCGGCT GCTCTACAGGAATG ACAACATGGGCT
GLUT2EX1.137	AGCACTAATT(C/A)TCTGTGGAGC	CTAAACAGAAAACACACAG CAC	ACTGCACACTGTCACACAG	TAGCTGTGTGACAT CTGGCACAGAAACAC CACAGCACTAATT
GLUT2EX1.164	CAGTGTGCC(T/C)CCATGCTCCA	GCAGAGTGCAGTGTGCC	GCTGTGCTGGAGCATG	TGCTTAGTGTGAGT CGCCAGAGCAAGCT CAGTGTGCC
GLUT4EX3.112	GGCACCCCTCA(C/G)CACCCCTGG	CCCTCCAGGCCCTC	AGAGGGCCAGGGT	CTCACGACTGGGCTG ATGATTCCATCCCTCC AGGCACCCCTCA
GMP-140.105	TTTCTCTTGT(A/G)ACAATGGCT	TGGAGCGGTGGCTCTA	CCCAACCCATTATCAGACCTA	TGGCACAGTTCCCTG CTGGTGGCTCCACCT GTCATTCTCTGT
GMP-140.164	CCACTGGTCA(A/C)CTACCGTGCC	AAGAGAAATGCCACTGGTC	GCAGGGTGGCACGGTA	GCTGGGGTGTGATCCT CTCTACAAGAGAATG GCCACTGGTCA

KLKEX3.253	GTTGCCACCC(C/G)AGGAACCGA	TCGTGGAGTTGCCAC	CCCCACTTCGGGTTCC	CCTGTCGCCCTGAT AGAACTGTCGGAGT TGCCCACC
KLKEX4.110	GTCAGAAGG(T/A)GACAGACTTC	AAGCCACGTCAGAAG	CGACACACAGCATGAAGT	AGCAATATCGGCCA TCGTGGCAAAAAGC CAAGTCAGAAGG
LAM1.103	CCAGTGTCA(GT/C)TGGTAAGTC	TGGCCCAGTGTCA	GCAAAGAAAGGAAAGAGAC TTACCC	CTGTGCCCTGCTGTA TGATTACTATGGCC CCAGTGTCAAG
LPL.177	TATGAGATCA(A/G)TAAAGTCAGA	CAACAATCTGGCTATGAG ATC	TGCTTCCTTGGCTCTGACTT	GTGCTCTGTTGACATA TAGTGACAACTCTGGG CTATGAGATCA
LPL.98	AATAAGAAGT(C/G)AGGCTGGTGA	CCATGACAAGTCTCTGAATA AGAA	CCAGAAATGCTCACCAAGCC	CCTGTAAGTCAGTCT CCTGACGCGATGACAA GTCCTCTGAATAAGAA GT
mACEEX13 R.NA	TGCTGGTCCC(C/T)AGCCAGGAGG	GCACCCCTCTGGCTGGTCC	TGACTGTCACCTGTTGGGA	CACTCACTGGCACGG TATAGTGTGGGATG CCCTCTGGCT
MRLEX2.545	CATGCGGCC(A/G)TGTAAAG	GGTGGCGTCATGCGC	CACATGATAGGGCTTTAAC AAT	GGAATGTCCTGGCGT CCATAATGTTGGCGT CATGCGGCC
NAT2.346	CAGGTGACCAT(T/C)TGACGGCAGG	CCTTCTCTGGCAGGTGACC	ACAATGTAATTCTGCCGTC	CTGTGAGTGTATGTAC GCTCCCTCTCTGCAG GTGACCA
NETEX11.123	AGTCTGCCT(T/G)CCTCTGGTG	GAAGTTCAGTCAGTCTGCC	CCCTGCAGACACTACACACC	GGGTGGGGTCACTCT GCAATTCCTGAAAGTTC GTCAAGTCCTGCCT
NETEX12.81	CTACGACGACCT(C)ACATCTTCCC	GCCACTCACCTACGACGA	CCAGGGGGAGAAGATG	CGGCTGGGGTAGGATC ATCTAAAGCCACTCA CCTACGACGAC

NETEX5.121	AATGGCATCA(A/C)TGCCTACCTG	GAGCCCTCCAATGGCATC	GTCGATGTGCAGGTAGGC	GCATGAAGGTCCATA ATCGCGAGGCCTCCAA TGGCATCA
NETEX7.112	TGGTTACATG(G/C)CCCCATGAAACA	TCTTCTCCATCTTGGTTAC A	TGTGACCTTGTGTTCATGG	CAGTGACATGCCGCT CAGTACATCTCTCTCCA TCCCTGGTTACATG
NETEX7.131	CACAAGGTCA(A/G)CATTGAGGAT	GCCCCATGAAACACAAGGTC	TGTGGCCACATCCTCAAT	CGGCAATAATGATGAT AGGTCCCCATGAAACA CAAGGTCA
NETEX7.73	CACCAAGGTTC(G/C)TCTCTGGTT	GCATCAACTGTATCACCAAGC TT	AGATGGCCAAACCCAGAG	CCTGGATATGACATGG AGCCTCACGATCAAC TGTATCACCAAGCTTC
NETEX9.157	TGCAATAACCA(A/G)GGTGAGTAGG	CGCCCTGTTCTGCATAACC	GCCCCAGCCCTACTCAC	CCAACCGATGCTACTG AGTCACGGCCCTGTCT GCATAACCA
OB.160	GATCAATGAC(A/G)TTTCAACAC	AATTGTCACCAAGGATCAAT GA	ACTCTCCTTACCGTGTGA A	CATTGCAACCCACTGA GATGGATTGTCACCA GGATCAATGAC
OB-R.174	GTAATTTTCC(A/G)GTCACCTCTA	TCACATCTGGTGGAGTAATT TTC	GCTGAAACTGACATTAGGG TGA	ACCGGATCTGCCGCT AGAATCATCTGGTGG AGTAAATTCC
PG1SEX1.396	GGGAGCAGGG(T/G)TTCTCCAGA	GCTGGGGGGAGCAGG	GGGGCTCTGGGAGA	CGAACACATGCCGCT GGATAAGCTGCCGGGG AGCAGGG
PLA2AEX2.42	GCCGCCGCCG(A/C)CAGGGCATC	CTTGCAGTGGCCGCC	AGGGCTGATGCCGCT	AGATAGAGTCGATGC CAGCTTGCAGTGGC CGCCGCCG
PLA2AEX3.104	TGCTGGACAA(C/A)CCGTACACCC	TGGACAGCTGTAAATTCTG CT	ATGAATAGGTGTGGGTGA CG	TGCCCTCATTTGACTC ATGGACAGCTGTAAA TTTCCTGCTGGACAA

PNMTEX3.181	GGAGGGCTGTG(A/T)GCCCAATCT	CCTTCCTGGTGGAGGCTGT	AGCTGGCAAGATCTGG	TGTGAGCTGTACT ACGGCTGCCTCTGT TGGAGGGCTGTG
PNMTEX3.251	GGGGGGCACC(T/A)CCTCCATC	GCTGAGGCCCTGGGG	CCAGGTACCAAGACTCCTC	TGTGAATAATGTGT GGCACTGAGGCCCTGG GGGGCACC
PNMTEX3.269	ATCGGGGCCCT(A/T)GGAGGAATCG	GCTGAGGCCCTGGGG	CCAGGTACCAAGACTCCTC	TGAGACTATTTAGGC TGTGCTCCCTCATC GGGGCCC
PON1.584	CCCTACTTAC(A/G)ATCCCTGGAG	TCACTATTTCTGACCCCT ACTT	CCCAAATACATCTCCAGGA	GAATCGCAGTTCAAG CGCATATTCTGTGAC CCCTACTTAC
PON2.949	AACATTCTAT(G/C)TGAGAAGCT	CCGCATCCAGAACATTTCTA ACTT	CATAAACTGTAGTCACTGTA GGCTCT	CAGTCCTGTGGATAG CACTCGTTCTCCGAT CCAGAACATTCTAT
SCNN1B.222	CACCAACTT(G/A)GCTTCAGCC	GGAGGCCACACCAACTT	CCGTGTCAAGGCTGGAAAG	GACTGGGATTACATG CTATGGAGGCCACA CCAACATT
SCNN1B.238	CAGCCTGACA(C/T)GGCCCCCGC	TTGGCTTCCAGCTGAC	GTGTTGGGCTGGGG	CACTCCGATGGCAG ATGAATTGGCTCC AGCCTGACA
SCNN1B.AA442	ACCTGCATTG(G/T)CATGTCAAG	CGCAGAGAGACCTGCAT T	GCAGGGACTCCTTGACAT	GCACCGTGTGCGAT CTATACAGAGAGAGA CCTGCAATTG
SCNN1G.172	GGCTCCCCA(T/C)GTCCAGAACG	GGAAACAGGCCCC	ACGGGGAGCTCTGG	AGCCAAGTGCAGGG TACATCCTGGAAACA GGCTCCCCCA
SCNN1G.21	TTCTGTCCAA(C/A)TTGGGGCC	CAGTATTGAGATGCTCTGT CCA	CCAGGTGCCACCGA	TCTCTCGTTGGATGT GAGCCAGTATTGAGA TGCTTCTGTCCAA

SCNN1GEX1.236	GTCGGGGCC(G/T)CTCCGGCCGG	CGTTGTGAAGTCGTGCC	CTGAGACCGCCCGGA	CAGTGACGTGAGTGC CATCTGTTGTGAAGT CGTGGCCC
SCNN1GEX2.219	GGTGTCCGGC(G/T)GCCGTCTGCG	GCATCGTGGTGTCCCC	GGAGGGGGCGCAGAC	CTCAGCAGTGTAGCAG CGCATCGCATCGTGG TGTCCCGC
SCNN1GEX3.259	GCGGAAAGTC(G/A)GCGGTAGCAT	GGGAGGAAGGGAAAGT	GAAGCCTTGTGAATGATGCT	CTTATGGCGCTGTGCG GCTATCGAGGAA GGGAAAGTC
TBXASEX11.88	CCCCCAGGC(G/A)CTGTGCTAGA	CGAGGTGGCTGGGCA	ACGGGCCATCTCTAGCAC	GATATGGGTGTACGTG AGTCTCGGGCCATCTCT AGCACAG
TBXASEX9.276	TGCCACCTAC(C/G)TACTGGCAC	CACACTTCTTTGCCACCT	AGGGTTGGGGCCAGT	CAACAAACTGCGCGAC GATGAAAACACACTT CTTTGCCACCTAC
TGF-B1.75	CTCATGGCCA(C/T)CCCGCTGGAG	TCCATGCTTCTCATGGCC	GGCCCTCTCCAGGG	TGTGCAATTGGGG CGCCCCCTTCTGCTT CTCATGGCCA
TRHREX1.56	GCAGAACTTA(G/C)ATGATAAAGCA	CAGGTACTAGAGTTCTGCA GAACCT	GGCTTGTGCGTGTATCA	AGCAGTAATGACAGC GTGCAAGGTACTAGA GTTTCTGAGAACTT A

References:

1. Singer-Sam & Riggs, *Methods Enzymol.* 225:344-351 (1993).
2. Greenwood & Burke, *Genome Res.* 6:336-348 (1996).
3. Halushka *et al.*, Pattern of single nucleotide polymorphisms in human genes.
5 *Nature Genet.* (Submitted).
4. Risch & Merikangas, *Science* 273:1516-1517 (1996).
5. Collins *et al.*, *Science* 278:1580-1581 (1997).
6. Collins *et al.*, *Science* 282:682-689 (1998).
7. Chakravarti, *Nature Genet.* 21:56-60 (1999).
- 10 8. Chee *et al.*, *Science* 274:610-614 (1996).
9. Wang *et al.*, *Science* 280:1077-1082 (1998); <http://www.genome.wi.mit.edu/SNP/human/index.html>.
10. Lipshutz *et al.*, *Nature Genet.* 21:20-24 (1999).
11. Shoemaker *et al.*, *Nature Genet.* 14:450-456 (1996).
- 15 12. Giaever *et al.*, *Nature Genet.* 21:278-283 (1999).
13. Pastinen *et al.*, *Clin. Chem.* 42:1391-1397 (1996).
14. Pastinen *et al.*, *Genome Res.* 7:606-614 (1997).
15. Pastinen *et al.*, *Hum. Mol. Genet.* 7:1453-1462 (1998).
16. Nikiforov *et al.*, *PCR Methods and Applications* 3:285-291 (1994).
- 20 17. Nikiforov *et al.*, *Nucleic Acids Res.* 22:4167-4175 (1994).
18. Head *et al.*, *Nucleic Acids Res.* 25:5065-5071 (1997).
19. Tobe *et al.*, *Nucleic Acids Res.* 24:3728-3732 (1996).
20. Delahunty *et al.*, *Am. J. Hum. Genet.* 58:1239-1246 (1996).
21. Chen *et al.*, *Genome Res.* 8:549-556 (1998).
- 25 22. Lyamichev *et al.*, *Nature Biotech.* 17:292-296 (1999).
23. Newton *et al.*, *Nucleic Acids Res.* 17:2503-2516 (1989).
24. Lo *et al.*, *Nucleic Acids Res.* 19:3561-3567 (1991).
25. Zhang *et al.*, *Proc. Natl. Acad. Sci. USA* 89:5847-5851 (1992).

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While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. An oligonucleotide array comprising one or more oligonucleotide tags fixed to a solid substrate, wherein each oligonucleotide tag comprises a unique known arbitrary nucleotide sequence of sufficient length to hybridize to a locus-specific tagged oligonucleotide, wherein the locus-specific tagged oligonucleotide has at its first end nucleotide sequence which hybridizes to, e.g., is complementary to, the arbitrary sequence of the oligonucleotide tag.
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2. A kit comprising:
 - 10 (a) an array comprising one or more oligonucleotide tags fixed to a solid substrate, wherein each oligonucleotide tag comprises a unique known arbitrary nucleotide sequence of sufficient length to hybridize to a locus-specific tagged oligonucleotide; and
 - (b) one or more locus-specific tagged oligonucleotides, wherein each locus-specific tagged oligonucleotide has at its first (5') end nucleotide sequence which hybridizes to, e.g., is complementary to, the arbitrary sequence of a corresponding oligonucleotide tag on the array, and has at its second (3') end nucleotide sequence complementary to target polynucleotide sequence in a sample.
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- 20 3. A method of genotyping a nucleic acid sample at one or more loci, comprising the steps of:
 - (a) obtaining a nucleic acid sample to be tested;
 - (b) combining the nucleic acid sample with one or more locus-specific tagged oligonucleotides under conditions suitable for hybridization of the nucleic acid sample to one or more locus-specific tagged
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oligonucleotides, wherein each locus-specific tagged oligonucleotide comprises a nucleotide sequence capable of hybridizing to a complementary sequence in an oligonucleotide tag and a nucleotide sequence complementary to the nucleotide sequence 5' of a nucleotide to be queried in the sample, thereby creating an amplification product-locus-specific tagged oligonucleotide complex;

5 (c) subjecting the complex to a single base extension reaction, wherein the reaction results in the addition of a labeled ddNTP to the locus-specific tagged oligonucleotide, and wherein each type of ddNTP has a label that can be distinguished from the label of the other three types of ddNTPs;

10 (d) contacting the complex with an oligonucleotide array comprising one or more oligonucleotide tags fixed to a solid substrate under suitable hybridization conditions, wherein each oligonucleotide tag comprises a unique arbitrary sequence complementary and of sufficient length to hybridize to a complementary sequence in a locus-specific tagged oligonucleotide, whereby the complex hybridizes to a specific oligonucleotide tag on the array; and assaying the array to determine the labeled ddNTPs present in the complex hybridized to one or more oligonucleotide tags,

15 thereby determining the genotype of the queried nucleotide in the sample.

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4. A method to aid in determining a ratio of alleles at a polymorphic locus in a sample, comprising the steps of:

25 (a) using a pair of primers to amplify a region of a nucleic acid in a sample, wherein the region comprises a polymorphic locus, whereby an amplified DNA product is formed;

(b) labeling an extension primer by a single base extension reaction to form a labeled extension primer, wherein the amplified DNA product is used as a template, wherein the extension primer comprises a 3' portion and a

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5' portion, wherein the 3' portion is complementary to the amplified DNA product and terminates one nucleotide 5' to the polymorphic locus, wherein the 5' portion is not complementary to the amplified DNA product, whereby a labeled dideoxynucleotide which is complementary to the polymorphic locus is coupled to the 3' end of the extension primer, wherein each type of dideoxynucleotide present in the reaction bears a distinct label; and

5 (c) hybridizing the 5' portion of the extension primer to one or more probes complementary to the 5' portion which are immobilized to known locations on a solid support.

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5. The method of claim 4 wherein two complementary strands of the amplified DNA product are present in the single base extension reaction.

6. The method of claim 4 wherein two complementary strands of the amplified DNA product are used as templates in the step of labeling.

15 7. The method of claim 4 wherein the label is a fluorescent label.

8. The method of claim 4 wherein the label is a radiolabel.

9. The method of claim 4 wherein the label is an enzyme label.

10. The method of claim 4 wherein the label is an antigenic label.

11. The method of claim 4 wherein the label is an affinity binding partner.

20 12. The method of claim 4 further comprising the step of:

(d) optically detecting a fluorescent label on the solid support.

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13. The method of claim 4 wherein the step of labeling employs at least two distinct dideoxynucleotides bearing distinct labels.
14. The method of claim 4 wherein the step of labeling employs four distinct dideoxynucleotides bearing distinct labels.
- 5 15. The method of claim 4 further comprising the steps of:
 - (d) comparing quantities of a first and a second label at a location on the solid support; and
 - (e) determining the ratio of nucleotides present at the polymorphic locus in the sample.
- 10 16. The method of claim 15 wherein the ratio of nucleotides present at two or more polymorphic loci is determined simultaneously.
17. The method of claim 4 wherein the sample comprises DNA from two or more individuals.
18. The method of claim 17 wherein the ratio of nucleotides present at two or more polymorphic loci is determined simultaneously.
- 15 19. The method of claim 4 wherein the solid support is selected from the group consisting of beads, microtiter plates, and oligonucleotide arrays.
20. A set of primers for use in determining a ratio of nucleotides present at a polymorphic locus, comprising:
 - 20 (a) a pair of primers which when in the presence of a DNA polymerase amplify a region of double stranded DNA, wherein the region comprises a polymorphic locus; and

(b) an extension primer which comprises a 3' portion which is complementary to a portion of the region of double stranded DNA and a 5' portion which is not complementary to the region of double stranded DNA, wherein the extension primer terminates one nucleotide 5' to the polymorphic locus.

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21. A kit comprising in a single container two or more of the sets of primers of claim 20.

22. A kit comprising in a single container:

10 (a) a set of primers of claim 20; and

(b) a solid support comprising a probe which is attached to a solid support, wherein the probe is complementary to the 5' portion of the extension primer.

23. The kit of claim 22 wherein the solid support is an oligonucleotide array.

24. The kit of claim 22 wherein the solid support is a bead.

15 25. The kit of claim 22 wherein the solid support is a microtiter plate.

26. A method to aid in determining a ratio of alleles at a polymorphic locus in a sample, comprising the steps of:

20 (a) labeling an extension primer by a single base extension reaction to form a labeled extension primer, using a DNA molecule as a template, wherein the extension primer comprises a 3' portion and a 5' portion, wherein the 3' portion is complementary to the DNA molecule and terminates one nucleotide 5' to a polymorphic locus, wherein the 5' portion is not complementary to the DNA molecule, whereby a labeled

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dideoxynucleotide which is complementary to the polymorphic locus is coupled to the 3' end of the extension primer, wherein each type of dideoxynucleotide present in the reaction bears a distinct label; and

(b) hybridizing the 5' portion of the extension primer to one or more probes 5 complementary to the 5' portion which are immobilized to known locations on a solid support.

27. The method of claim 26 wherein two complementary strands of the DNA molecule are present in the single base extension reaction.
28. The method of claim 27 wherein each complementary strand of the DNA molecule is used as a template to label an extension primer. 10
29. The method of claim 26 wherein the label is a fluorescent label.
30. The method of claim 26 wherein the label is a radiolabel.
31. The method of claim 26 wherein the label is an enzyme label.
32. The method of claim 26 wherein the label is an antigenic label.
- 15 33. The method of claim 26 wherein the label is an affinity binding partner.
34. The method of claim 26 further comprising the step of:
 - (c) optically detecting a fluorescent label on the solid support.
35. The method of claim 26 further comprising the steps of:
 - (c) comparing quantities of a first and a second label at a location on the 20 solid support; and

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- (d) determining the ratio of nucleotides present at the polymorphic locus in the sample.

36. The method of claim 35 wherein the ratio of nucleotides present at two or more polymorphic loci is determined simultaneously.

5 37. The method of claim 26 wherein the sample comprises DNA from two or more individuals.

38. The method of claim 34 wherein the ratio of nucleotides present at two or more polymorphic loci is determined simultaneously.

10 39. The method of claim 26 wherein the step of labeling employs at least two distinct dideoxynucleotides bearing distinct labels.

40. The method of claim 26 wherein the step of labeling employs four distinct dideoxynucleotides bearing distinct labels.

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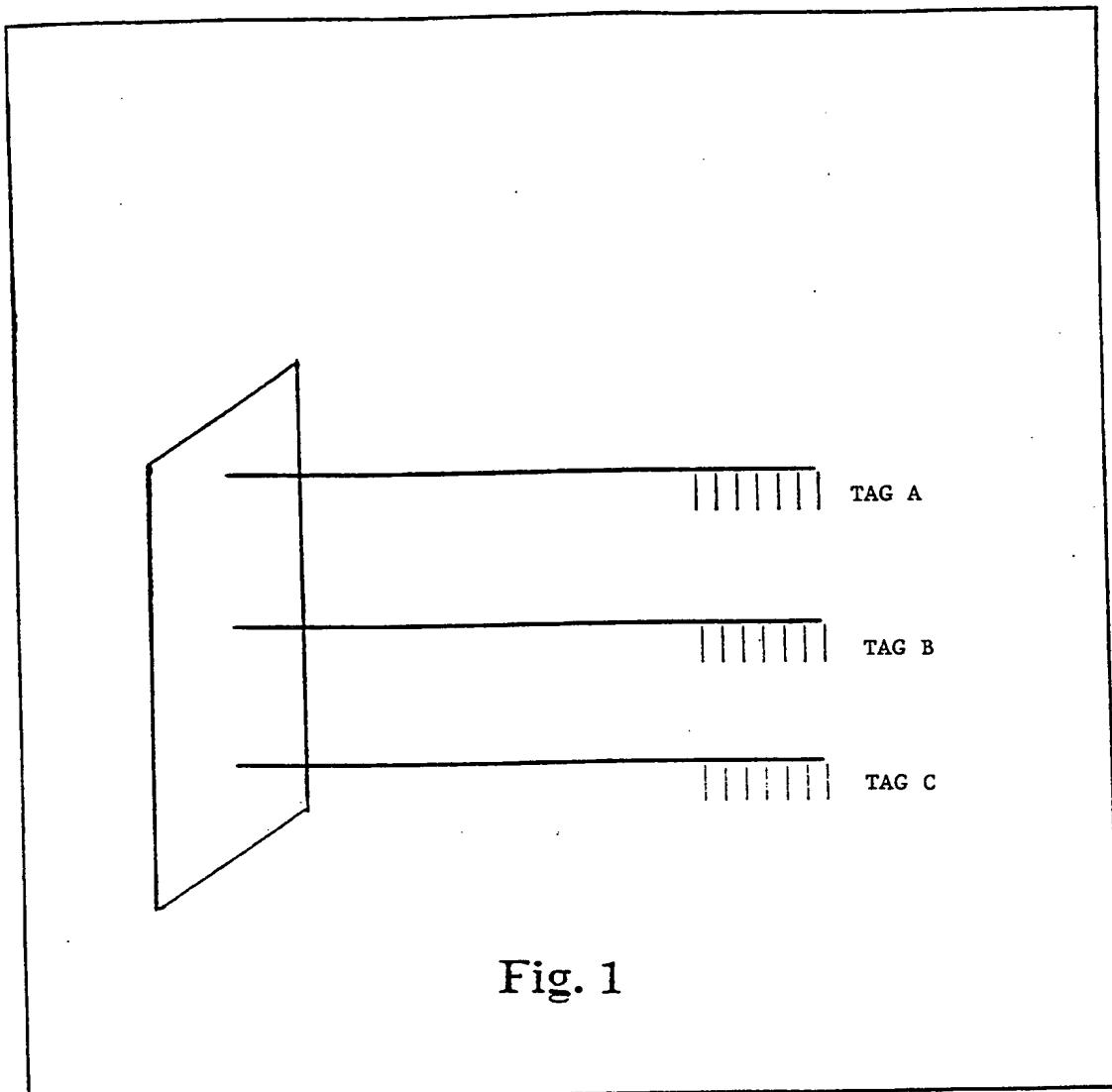


Fig. 1

Locus-specific tagged oligonucleotide:

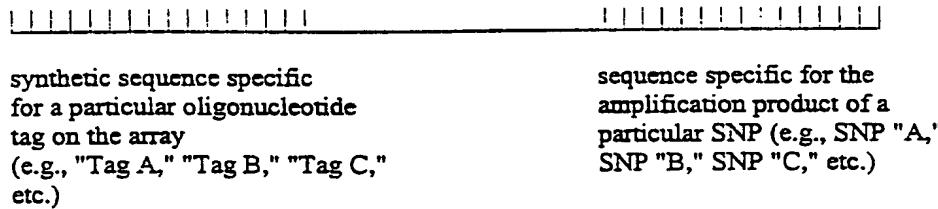


Fig. 2

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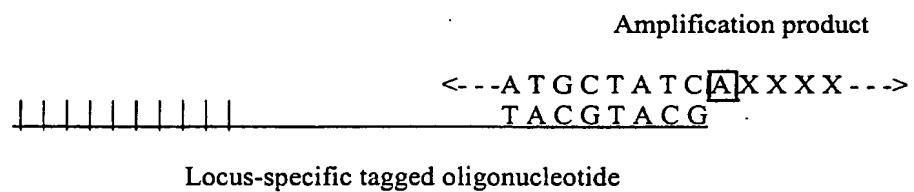


Fig. 3

Amplification product

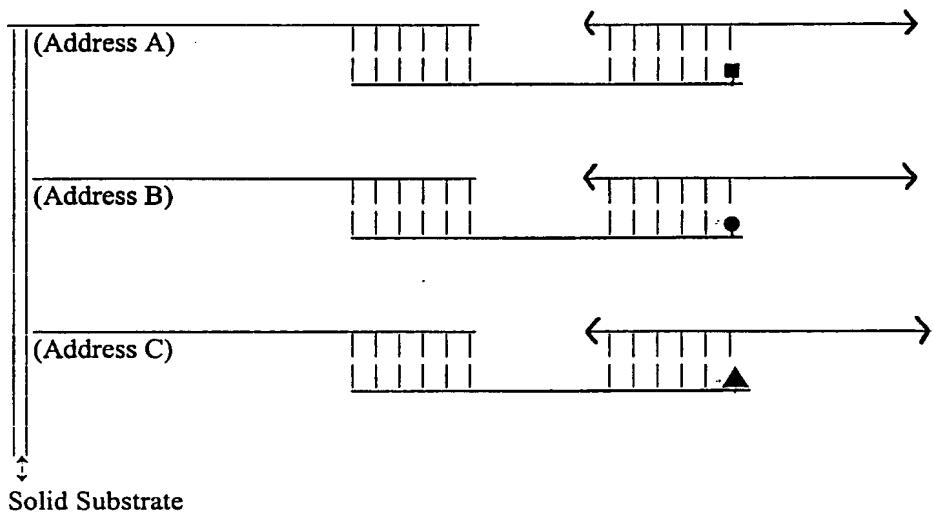
<-- A T G C T A T C A X X X X -->

Locus-specific tagged oligonucleotide

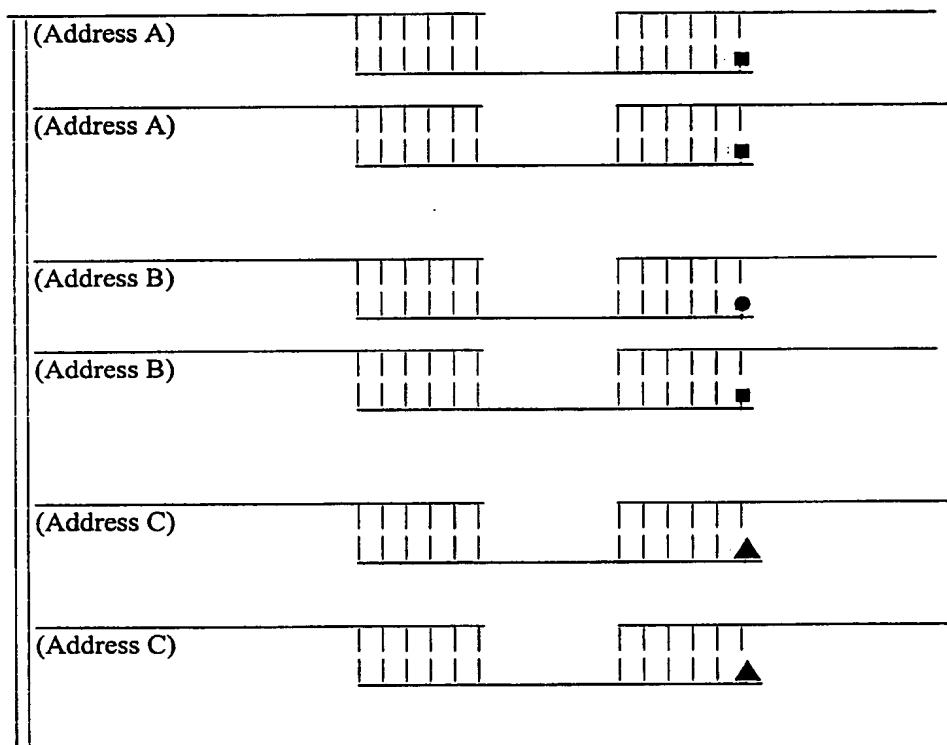
ddNTPs: T A G C

Fig. 4

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**Fig. 5**

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**Fig. 6**

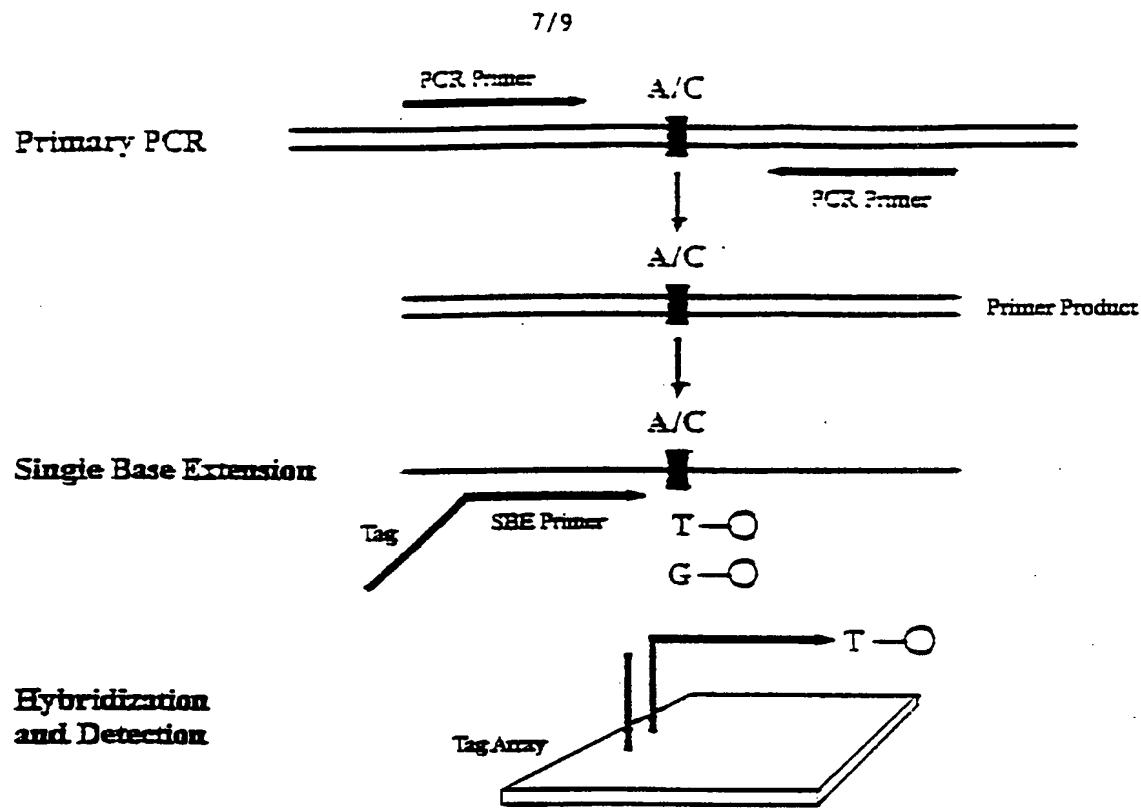


Fig. 7

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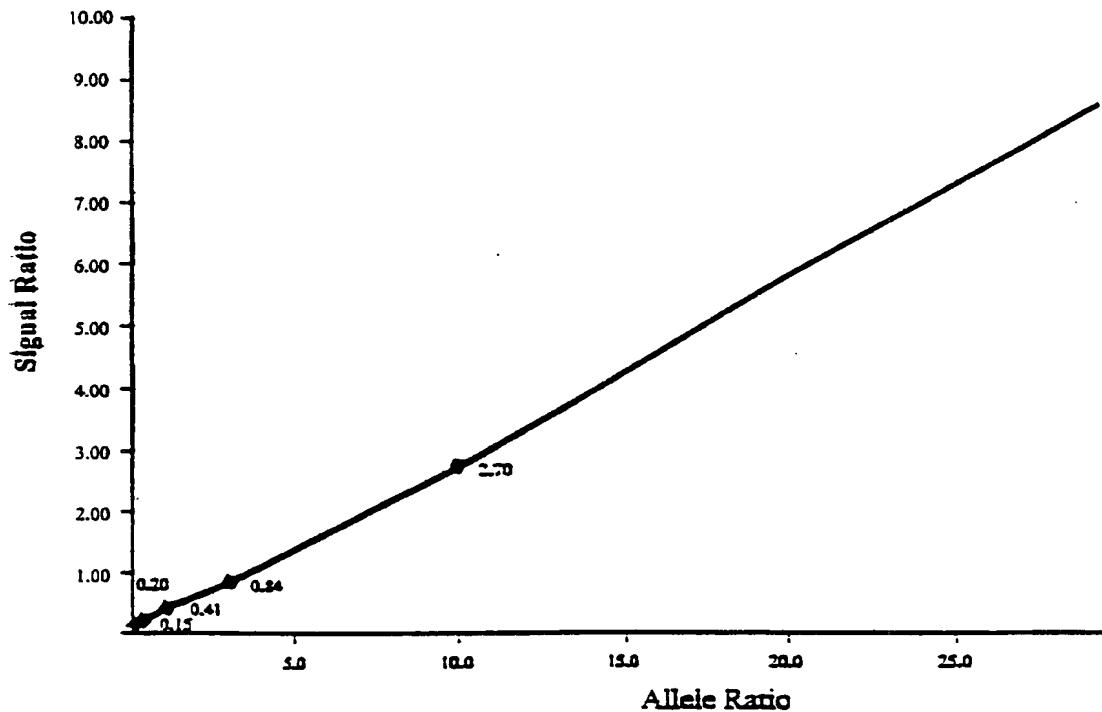


Fig. 8

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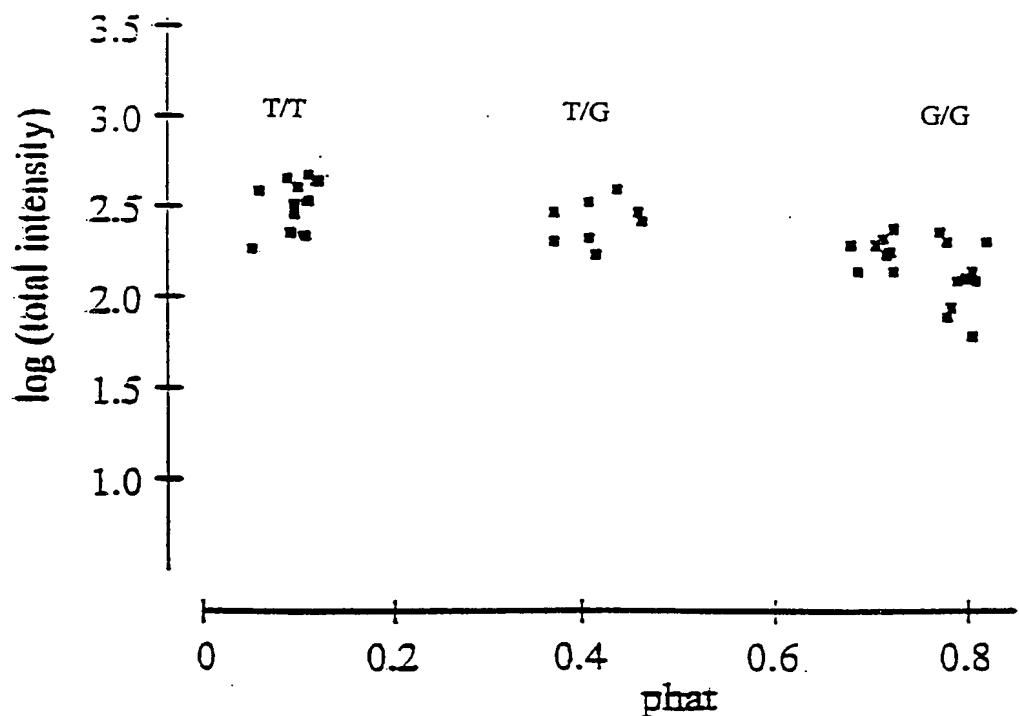


Fig. 9

GMP-140.25	TACTCCAGGG/T/G)TGCAATGTCC	GCATCACTTCTACTCCAGG	TGAGGGCTGGACATTGC	GGTGACAGTGTATTATCTGCATCACTTCTCTTCACTCCAGGG
GMP-140.30	GAAGCCCCCA(G/A)TGAAGGAACC	CAGCACCTGGAAAGCCC	ACACAGTCATGGTTCCTTC	GATCTGTCAAAAGTGTATGGCGTCAGCACCTGGAAGCCCCCA
GNB3EX10.144	CATCATCTGC(G/A)GCATCACGTC	CCCACAGAGGCATCATCTG	CACTGAGGGAGAAGGCCA	TATCTTATTCTCGACCGGGCTCCACGGAGAGCATCATCTGC
GSY1EX16.210	CATCGTGCAC(G/C)CAGAGTGGCC	GGCAACATCCGTGC	TGCAAGGACACTGGC	CCTGTCTACCATGCAATACTGGGCAACATCCGTGC
GSY1EX3.117	GGAGGGCTGG(A/G)AGGGAGAGCT	GGCCCTGGAGGGCTG	GGTATCCCAGAGGCTCTCCC	TATATGCAGTGTGGTGTTCGCTATCCCAGAGCTCTCCCT
GSY1EX8.43	AACGGCAGCG(A/G)GCAGACAGTG	GCAGGTGAACGGCAGC	AAGAAGGCAACCACTGCTG	GACGGGGGTGCTCATCATATCTGGCAGGTGAACGGCAGCG
HUNGUANCY.C.2	ATGTTGGCT(C/G)AGGACCCAGC	TGGAGCCATGTGGGC	CGCTCAGGCTGGTCC	GCTGGGCAATGTGTAC TACTCTGATGGAGCGATGTGGGCT
ICAM1.117	TTCCTGGAC(G/A)GGCTGTTCCC	CGTGGCTGTTCCCTGGA	CCTCCGAGACTGGGAACA	CTGTCATATGGCTCTGCTCTAGACCGTGGTC TGTTCCTGGAC
ICAM1EX1.683	TTGCAACCTC(A/C)GCCTCGCTAT	TGCTACTCAGAGTGTCAACC	GGGAGCCATAGGGAGG	GTCTCGTCATCTGTGAGTGGCTACTCAGAGTTGCAACCTC
ICAM1EX2.115	GACCAGCCCA(A/T)GTTGTGGC	CACCTCCCTGTGACCAAGCC	GGGTCTCTATGCCAACAA	ACGCCACACTGATAAC TATGCACCTCCCTGTGACCAAGCCCCA

ICAM1EX6.254	GGTCACCCGC(G/A)AGGTGACCGT	AGGGGAGGTACCCG	AGCACATTACCGTCACC	GTGCTGGGTTCGCAT TCATCGCACATTCAC GGTCACCT
ICAM1EX6.39	GATGGCCCCC(G/A)ACTGGACGAG	TTTCCAGATGGCCC	GACAATTCCCTCTCGTCAG	CCAATAGGTGCTCAC GTCAATGTTTTCGA GATGGCCCCC
ICAM2EX2.63	AAAGAAGCTG(G/A)CGGTTGAGCC	CGTGAGGCCAAAGAAGCT	CCCTTTGGCTCAACC	TTGGCTCATTTGCATG GCGCCACGTGAGGCC AAAGAAAGCTG
IRS-2.AA1057	CAGGGCCGG(G/A)CGCCGCTCA	GTGCCCCCAG	CAACGATGAGGGGC	TGCTCGCTTGTGATCG ACTGTTGCCACCGCC CAGGGCCCCG